ANNEX E

RECOVER SYSTEM-WIDE EVALUATION OF

CENTRAL EVERGLADES PLANNING PROJECT (CEPP)

This page intentionally left blank

0 EXECUTIVE SUMMARY

The REstoration COordination and VERification team (RECOVER) system-wide evaluation of Central Everglades Planning Project (CEPP) performance provides the evaluation required for all Comprehensive Everglades Restoration Plan (CERP) projects under the 2003 programmatic regulations. This report is a broad-scale evaluation of ecological effects of the CEPP alternatives on Lake Okeechobee, the Northern Estuaries (Caloosahatchee and St. Lucie), Greater Everglades (Water Conservation Areas [WCA] and Everglades National Park [ENP]), and Southern Coastal Systems (Southwest coast, Florida Bay, and Biscayne Bay). The scope of the review covers all areas expected to be improved by CEPP, and all areas outside of the CEPP project boundary which fall within the overall CERP program area. The review includes the use of a broad range of evaluation tools, performance measures, and best professional judgment that reach beyond the tools and expertise of the traditional USACE planning process. The tools and professional backgrounds of the reviewers represent decades of experience studying and modeling the ecology of south Florida. The purpose of the review is three-fold: 1) to provide insight into whether some alternatives performed better ecologically than others, 2) to indicate whether alternatives may lead to unintended ecological conditions, and 3) to investigate the effects of CEPP alternatives that could potentially conflict with the goals of CERP on a regional scale. The following key findings are provided:

System-wide Performance - All areas affected by CEPP can be improved by the proposed alternatives. These include the northern estuaries, the greater Everglades, and the southern coastal systems. Overall, it appears that the alternatives that provide the most water to Everglades National Park provide the least water to Biscayne National Park, and vice versa, almost certainly due to the type of seepage management and operational protocols employed. In addition, some performance issues were recognized in the St. Lucie Estuary, WCA 2 and WCA 3B under alternative 4 that could potentially be improved with minor operational changes. These issues will be addressed in the Savings Clause and Assurances analyses and will continue to be addressed with adaptive management during CEPP's implementation and operation.

Adaptive Management - There was a determination that proceeding with an adaptive management approach can further increase the benefits of CEPP and positively influence the implementation of CEPP in sensitive areas. Adaptive management provides a means to learn during implementation and operations through monitoring and assessment in order to ensure restoration performance, while minimizing impacts and reducing risk overall.

Full CERP Implementation Consistency - Because modeling resources and capability did not allow for full system-wide CERP runs, RECOVER was unable to provide a complete understanding of how CEPP would function as part of full CERP implementation. CEPP project features formulated to achieve incremental system-wide restoration benefits in the near-term may not function as well once all of CERP is implemented as envisioned in the Water Resource Development Act of 2000. This may require adapting project features, such as the blue shanty levee, to achieve the full set of restoration benefits stated under CERP as additional CERP projects are implemented. Nonetheless, the CEPP project represents an important near term-incremental step towards restoration of the south Florida Everglades ecosystem.

Future CERP Increments – Future increments of CERP should consider the need for more storage, decompartmentalization, conveyance, and any associated seepage management to meet full CERP restoration goals for water quantity, quality, timing, and distribution.

Climate Change - The need for more reliable sources of storage may become more apparent as a result of anticipated changes in climate. The National Climate Assessment and Development Advisory Committee's National Climate Assessment 2013 draft report estimates the following potential effects as a result of climate change: increased evapotranspiration rates due to higher temperatures; changes in rainfall intensity, seasonal timing, and amounts; sea-level rise; and increased frequency of tropical storms. Future planning efforts should evaluate scenarios of these climatic drivers to determine plans that are robust enough to address climate variation. In addition, scientists and managers should continue monitoring and associated analyses to understand the effects of climatic drivers on system-wide indicators that are envisioned to be restored under CERP.

Lake Okeechobee - One of the CEPP project planning constraints was to remain within the existing water regulation schedule for Lake Okeechobee and thereby not impact the Lake's ecology. However, hydrologic modeling indicated that there are periods where the Lake's water level is held ~6-12 inches higher than the future without (FWO) levels, while remaining within the current schedule. The higher water events are expected to be rare enough to avoid additional long-term ecological impacts.

Northern Estuaries - Modeling of the hydrology, salinity, and associated ecology of the St. Lucie and Caloosahatchee Estuaries, referred to as the northern estuaries, showed a small reduction in fresh water discharges from Lake Okeechobee to the northern estuaries. Although the difference was not statistically significant, this change is moving 'in the right direction' for reducing peak flow events. Ecological projections for oysters and sea grasses, key species in the estuaries, indicated improvements with CEPP alternatives. Modeling indicated less fresh water entering the St. Lucie Estuary during low-flow times, when small amounts of fresh water are needed. CEPP operations and future increments of CEPP should seek to address this alteration to the base flow into the estuaries during dryer times. Future operations of the Indian River Lagoon-South project could be optimized to help provide these base flows.

Greater Everglades – RECOVER data and modeling showed improved ecological performance for fish, wading birds, and apple snails in northern and central WCA 3A and Shark River Slough for all alternatives. Improved hydroperiods and sheetflow in WCA 3A, WCA 3B, and Everglades National Park are expected to result in less soil oxidation, which promotes peat accretion necessary to rebuild the complex mosaic of habitats across the landscape. Hydrologic stages in WCA 2 are slightly decreased during dry years and may require adaptive management of operations to avoid performance issues. In comparing alternatives against each other, the differences between them were smaller. Alternative 1 may provide sheetflow to a larger area in WCA 3A, while alternatives 3 and 4 provide more water to Shark River Slough and the southern marl prairies, improving conditions for fish, alligators, tree islands and ridge and slough habitat. Overall, alternative 4 appears to make the most 'efficient' use of the limited new water that CEPP is adding to the Everglades according to the surface flow vectors, sheetflow information, wading bird and small fish performance indicator outputs. The use of the water is efficient because it provides a focused flow of water through the Blue Shanty Flowway and does a better job of rehydrating northeast Shark River Slough than any of the other alternatives. The wading bird results were mixed among the various alternatives, where wading bird nesting models indicated wood storks showed the most improvement with alternative 1 and 2, but the wood stork habitat suitability index tool indicated that alternatives 3 and 4 provided more favorable habitat. Concerns were expressed by some RECOVER scientist that the Blue Shanty Levee in alternative 4 could limit restoration of WCA-3B in the future. Suggestions were made to move the levee east or to remove it from the alternative altogether. Given these concerns, the PDT may use adaptive management to determine the need for, best use of, and best placement of the levee. A preference was also expressed to use passive structures rather than pumps in order to lower the costs of operations/maintenance and increase the natural aspects of Everglades restoration.

Southern Coastal Systems - The Southern Coastal Systems are the southernmost estuaries in Florida, which require fresh water inputs to reduce salinity levels and maintain ecologically favorable brackish conditions. All CEPP alternatives show decreased salinity compared to the FWO in Florida Bay, with associated ecological improvements for submerged aquatic vegetation (SAV) habitat and key species such as seatrout, pink shrimp, and crocodiles. Alternative 4, which yielded more flow through Shark River Slough, improves estuarine salinity conditions over the other alternatives. The differences among alternatives were much less than the differences when comparing each alternative to the FWO. Based on the hydrologic connections between Shark River Slough and the southwest coastal areas of Florida, there is high likelihood that the southwest coastal areas would experience significant ecological benefits from any CEPP alternative; however these could not be quantified during CEPP evaluations due to the lack of salinity and ecological models available in that area of the estuaries.

Biscayne Bay may have reduced fresh water flows in the dry season compared to ECB and FWO in the area of CERP's Biscayne Coastal Wetlands Project and Biscayne National Park, which could have adverse ecological effects. The RECOVER recommended and the CEPP team agreed to investigate this further during the Savings Clause and Assurances modeling and analyses.

RECOVER provided support throughout the development of CEPP's TSP from the earliest stages of CEPP's planning, including extensive tools and expertise. Forecasting tools included performance measure models and habitat suitability indices that were developed and approved by RECOVER interagency scientists previous to CEPP, which alleviated the need for CEPP to create and gain verification of new ecological models during its accelerated planning schedule. Expertise offered by RECOVER included input from scientists in 10 agencies and both Tribes of south Florida, consisting collectively of decades if not centuries of scientific knowledge of the Everglades, Lake Okeechobee, and the estuaries. The RECOVER system-wide evaluation of Alts 1-4, reported in this document, was a significant contribution to the development of the TSP because it indicated some areas of concern in the ecosystems under the alternative scenarios. The system-wide evaluation thereby guided the PDT to areas where refinements were needed, and refinement was undertaken during the optimization of the TSP to produce the final alternative.

Contents

1 TRANSMITTAL LETTER

REstoration COordination and VERification (RECOVER) Evaluation Team Regional Evaluation Report

Date: February 26, 2013
To: Project Managers and Planning Technical Leads
Central Everglades Planning Project

Dear Project Team Managers and Planning Technical Leads,

RECOVER has completed its regional evaluation of the Central Everglades Planning Project (CEPP) alternative plans and our final report is attached. RECOVER's evaluation of project alternatives fulfills the following requirements as prescribed by the Programmatic 2003 Comprehensive Everglades Restoration Plan (CERP) Regulations 33 Code of Federal Regulations 385.20 (e)(2):

1. Support project teams to achieve consistency with the CERP's goals and objectives;
2. Document the performance of the project alternative plans using RECOVER approved system-wide performance measures, project performance measures (when appropriate) and best professional judgment. RECOVER determines the ability of each alternative plan to meet the targets established for each performance measure and describes the resulting effects upon the natural system;
3. When appropriate, RECOVER evaluations include a qualitative analysis on how the project fulfills CERP goals and objectives;
4. Suggest improvements to the project, which if pursued could improve project performance or enhance benefits to the natural system;
5. Provide insight, if possible, and alert the project teams of any inconsistent modeling assumptions for the project as originally modeled in the CERP.

Recommendations discussed within the RECOVER regional evaluation report are more conceptual in nature. The Project Team may select to incorporate these recommendations into preliminary designs to improve project performance or may chose to carry them into future CERP project planning and implementation efforts.

RECOVER provided its regional evaluation to satisfy the need for timely reporting as part of the new CEPP planning process, while bringing forward as much system-wide science as possible. Because modeling resources and capability didn't allow for full system-wide CERP runs, RECOVER was unable to help provide a complete understanding of how CEPP would function with full CERP implementation. RECOVER was able to provide several highlights to the team on January 23, 2013, regarding beneficial performance of CEPP alternatives and performance issues to consider during design, construction, and operations of this project, as well as some recommendations on how to handle the uncertainty associated with full CERP implementation. These highlights are restated in the executive summary of the report.

Best regards,

RECOVER Council of Chairs: (Fred Sklar, Agnes McLean, Patti Gorman, Steve Traxler, Gretchen Ehlinger)

2 INTRODUCTION

2.1 Background and Purpose

This report documents the Restoration Coordination and VERification (RECOVER) team system-wide/regional evaluation of the Central Everglades Planning Project (CEPP) required by the CERP programmatic regulations 33 Code of Federal Regulations 385.20 (e)(2). RECOVER is an independent (from project delivery team [PDT]), interagency team made-up of scientists charged with helping PDT's ensure their project's plans, designs, and performance are fully linked to the goals and objectives of CERP. This report documents the performance of the project alternatives using RECOVER approved system-wide performance measures (PM), project hydrologic model output, other information sources and evaluation tools not approved by RECOVER, and best professional judgment. It also highlights the ability of each alternative to meet RECOVER system-wide/regional performance targets and documents expected effects on the natural system.

2.2 CEPP Goals and Objectives

CEPP goals and objectives are consistent with CERP's, as described in **Table 2-1** – Goals and objectives of Restudy and CEPP in Section 01 of the PIR. CEPP focuses on delivering additional water which meets the state water quality requirements during the dry season to improve hydroperiods and sheetflow through the Central Everglades system. A storage is included as part of a flow equalization basin (FEB) to accept water form LO to reduce high volume discharges to estuaries and improve the quality of estuarine habitat (e.g., oyster and SAV).

Table 2-2-1. Comparison of CEPP and CERP Objectives

RESTUDY GOAL: Enhance Ecological Values	
CERP Objective	*CEPP Objective*
Increase the total spatial extent of natural areas	
Improve habitat and functional quality	Restore seasonal hydroperiods and freshwater distribution to support a natural mosaic of wetland and upland habitat in the Everglades System
	Improve sheetflow patterns and surface water depths and durations in the Everglades system in order to reduce soil subsidence, the frequency of damaging peat fires, the decline of tree islands, and salt water intrusion
	Reduce high volume discharges from Lake Okeechobee to improve the quality of oyster and SAV habitat in the northern estuaries
Improve native plant and animal species abundance and diversity	Reduce water loss out of the natural system to promote appropriate dry season recession rates for wildlife utilization
	Restore more natural water level responses to rainfall to promote plant and animal diversity and habitat function

RESTUDY GOAL: Enhance Economic Values and Social Well Being	
Increase availability of fresh water (agricultural/municipal & industrial)	Increase availability of water supply to the Lake Okeechobee Service Area
Reduce flood damages (agricultural/urban)	
Provide recreational and navigation opportunities	
Protect cultural and archeological resources and values	

Project goals and objectives included constraints to ensure that the proposed project would not reduce the level of service for flood protection, protect existing legal users, and meet applicable water quality standards for the natural system. This is consistent with the Yellow-book constraints.

2.3 Model Assumptions and Project Alternatives

As part of the RECOVER regional evaluation, the future without project (FWO) alternative was compared to several alternatives aimed at improvements in storage, decompartmentalization, sheetflow enhancement, and seepage management as proposed in the following CERP components:

- Everglades Agricultural Storage Reservoirs (G)
- Flow to Northwest and Central Water Conservation Area 3A (II and RR)
- Water Conservation Area 3 Decompartmentalization and Sheetflow Enhancement (AA, QQ and SS)
- Dade-Broward Levee/Pennsuco Wetlands (BB)
- Bird Drive Recharge Area (U)
- L-31N Improvements for Seepage Management and S-356 Structures (V and FF)
- Everglades Rain-Driven Operations (H)

Key Assumptions regarding the FWO include:

- Lake Okeechobee Regulation Schedule Study (2008) for Lake Okeechobee operations.
- 1st and 2nd generation CERP projects: C-43 and Indian River Lagoon South (C-44) storage reservoirs are in place to help reduce high Lake Okeechobee and basin flows to the estuaries, as well as provide low flows to stabilize salinities during the dry season.
- Additional Stormwater Treatment Areas and one Flow Equalization Basin (FEB) are in place as part of the state's water quality strategies to meet applicable state water quality standards.
- 1st and 2nd Generation CERP projects: Site 1 impoundment and Broward County Water Preserve Area projects are in place for both seepage management and sheetflow enhancement benefits, as well as secondary nutrient reduction benefits.

- 2nd generation CERP projects: C-111 Spreader Canal and Biscayne Bay Coastal Wetlands to help manage seepage in the southern end of the south Dade conveyance system, spread water across coastal wetlands and stabile nearshore salinities in Biscayne Bay.
- Everglades Restoration Transition Plan (ERTP) regulation schedule is in place for water conservation area 3A
- The following non-CERP projects are in place: Modified water deliveries 1-mile bridge on the eastern portion of Tamiami Trail, the 8.5 square mile levee and south Dade C-111 detention areas.

Project Alternatives:

Project alternatives were formulated for storage and operations above the redline (L-4, L-5, L-6 canals), which affect the Northern Estuaries and Lake Okeechobee. Project alternatives were formulated for conveyance, decompartmentalization, and seepage below the redline, which affect the Greater Everglades and Southern Coastal Systems. Ultimately four project alternatives (alternative 1, 2, 3, and 4) were compared to the FWO, and are depicted in **Figure 2-1** and **Figure 2-2**. A detailed description of the alternatives can be found in Section 3 of the Project Implementation Report (PIR). The majority of the project features considered in each CEPP alternative are consistent with an incremental version of CERP components or projects. However, two features, the FEB and Blue Shanty Levee, are new compared to what was originally envisioned for CERP. Limited modeling resources and capability did not allow for full system-wide CERP runs and RECOVER was unable to provide a complete understanding of how CEPP alternatives would function with full CERP implementation. Project features formulated to achieve incremental system-wide restoration benefits in the near term may not function as well with full CERP implementation as envisioned in the 2000 Yellow-book Plan. This may require adapting project features in the future, such as the blue shanty levee and/or pursuing additional sources of storage in addition to the FEB, to achieve the full set of restoration benefits envisioned under CERP. Ultimately, the CEPP project alternatives represent an important near term incremental step towards restoration of the south Florida Everglades ecosystem.

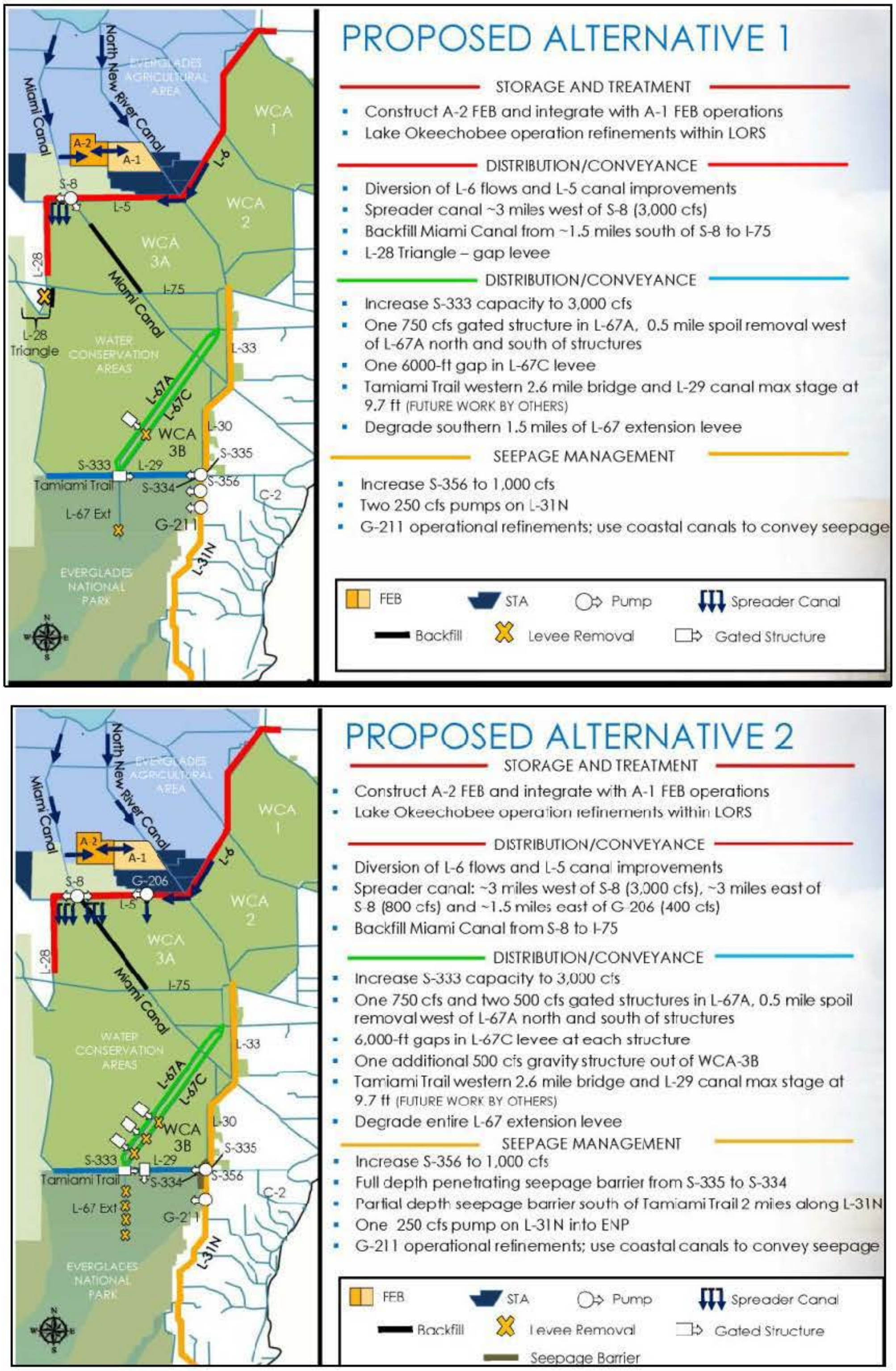


Figure 2-1 – CEPP Project Alternatives. Project features considered in project alternatives 1and 2 that were evaluated in comparison to the future without project in this RECOVER system-wide evaluation report.

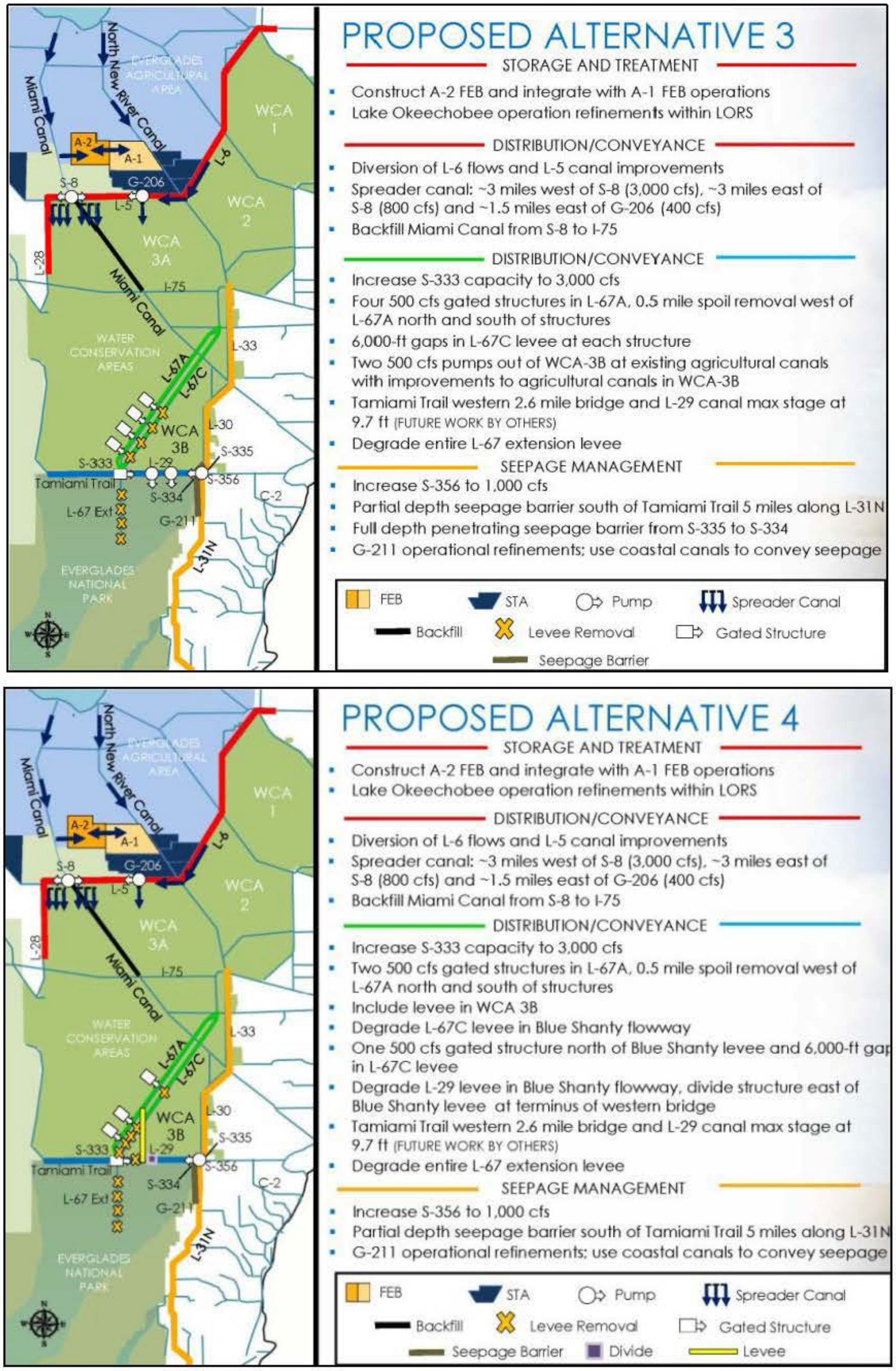


Figure 2-2 – CEPP Project Alternatives. Project features considered in project alternatives 3 and 4 that were evaluated in comparison to the future without project in this RECOVER system-wide evaluation report.

2.4 Uncertainty

Model uncertainty can be characterized in several forms (RECOVER, 2002), but generally they fall into two categories: knowledge uncertainty or natural variability uncertainty. Knowledge uncertainty relates to errors in how a particular species or parameter will respond to various environmental and habitat conditions. Knowledge uncertainty can be measured using calibration statistics for the hydrologic models which can be propagated to the ecological models that use hydrologic output. The limits of a model's representation of actual factors or conditions can be described in model documentation reports. Natural variability relates to the temporal and spatial uncertainty with each input and output in the model and is further complicated by climate change nonstationarity. The significance of both types of model uncertainty is that it can pose a risk to identifying and implementing the best project plan to achieve restoration goals and objectives. Scenario analysis can be used to evaluate variations of an alternative which is more robust (perform better under a range of future conditions) to help minimize the risk associated with natural variability uncertainty. Adaptive management is another tool that can help reduce uncertainty associated with implementing the best alternative plan and operations to meet restoration performance goals.

Knowledge Uncertainty

Planning Uncertainty

The RECOVER regional evaluation made assumptions about which projects would be implemented for the FWO and CEPP alternatives (See section 2.2). If any of these projects are delayed or are not implemented, the results for each alternative could change. This uncertainty is consistent for all project planning alternatives for any restoration project and is minimized by only including projects that have a signed Chief of Engineers Report or those that have been authorized by Congress or state governing bodies.

Model Uncertainty

The hydrologic models used for CEPP evaluation are the Regional Simulation Model Basins Model (RSMBN) and Regional Simulations Model for Glades Lower East Coast Service Area (RSMGL). The RSMGL model has reasonable performance accuracy as indicated by the calibration and validation report (See Appendix H). RSMGL is calibrated using historical stage data from January 1, 1984 to December 31, 1995. Of the 336 gages used for stage calibration, 100% of the gages meet the acceptability criterion for both bias (+/- 1.0 ft) and RMSE (+/- 2.0 ft). None of the gages violated the pre-set bias and RMSE threshold considerations. Overall, the mean and the standard deviation of absolute bias for the calibration period were 0.21 ft and 0.18 ft, respectively. Similarly, the mean and standard deviation values of RMSE for the calibration period were 0.54 ft and 0.25 ft, respectively. Historical stage data from January 1, 1981 to December 31, 1983, and January 1, 1996 to December 31, 2000 are used for model validation. In general, the model performed extremely well during the two validation periods. For each validation period, these percentages changed to 98.4% and 99.4 %, respectively. Overall, the mean and the standard deviation of absolute bias for the validation period were 0.26 ft and 0.29 ft, respectively. Similarly, the mean and standard deviation values of RMSE for the validation period were 0.59 ft and 0.35 ft respectively. A full description of model accuracy is contained in Appendix H – Benefit Model for each indicator region used in the RSMGL model.

Performance Measure and Ecological Planning Tool Uncertainty

The CEPP regional evaluation is based on technical evaluation performed by each RECOVER regional team. This evaluation is performed using both RECOVER approved performance measures, as well as other information (i.e., performance measures in development, corresponding assessment data, and other reports) that have not yet completed RECOVER scientific review and approval. RECOVER performance measure uncertainty is typically described in the RECOVER documentation sheets found at www.evergladesplan.org/pm/recover/eval_team_perf_measures.aspx. Those performance measures that have been reviewed and approved by RECOVER have more certainty based on scientific agreement, as opposed to other evaluation methods and tools that have not been reviewed and approved by RECOVER and are still being further developed and vetted, such as the ecological planning tools used in this evaluation. The ecological planning tools used as other information sources have model documentation reports that explain their accuracy and uncertainty, which are referenced in this report, where available.

Knowledge Uncertainty

The performance measure and ecological planning tools models are simplifications of the real relationships between hydrology and a particular indicator of interest. Errors can result based on known and unknown responses of species and habitats to various environmental and other habitat conditions. This type of uncertainty is inherent with any ecosystem restoration project and is minimized by using the best available science to develop and interpret model results. In addition, uncertainty is addressed by proceeding with project implementation through an adaptive management approach that tests hypotheses about the best project design and operations to achieve desired results.

Climate Change Uncertainty

The RSM model uses historic 41 year period of record (1965-2005) of rainfall and hydrology to simulate interaction of surface water/groundwater, evapotranspiration, and water management (movement of water through canals, structures, seepage, and overland flow or estuarine flow) to estimate the flow, water depths and durations, and salinities in the estuaries. Project infrastructure (e.g., canals, water control structures) and operations are portrayed in abstraction that generally mimic the intent of the project features while not matching the exact mechanisms by which these operations would be achieved in the actual conditions. Climate change nonstationarity means that the past climatic conditions (41 year period of record for the hydrologic models) are not indicative of future climatic conditions. To address this concern, some of the model evaluations and performance measures recommend looking at extreme years (Dry, Wet) in addition to average conditions to better understand, which alternatives are more robust to varying climatic conditions.

2.5 Evaluation Process and Organization

RECOVER regional teams (Northern Estuaries, Lake Okeechobee, Greater Everglades, and Southern Coastal Systems) held technical meetings to evaluate project alternatives using approved project performance measures, other best available scientific information, and best professional judgment. These evaluations were performed at a regional level to help in understanding the regional hydrologic and ecologic performance implications of each alternative. This RECOVER system-wide evaluation report is organized by four regional areas which are potentially affected by the project : 1) Lake Okeechobee; 2) Northern Estuaries – St. Lucie and Caloosahatchee River Estuaries; 3) Greater Everglades – Water Conservation Areas and Everglades National Park; and 4) Southern Coastal Systems – Florida

Bay, Biscayne Bay, and Southwest Florida Coast. A summary of this RECOVER system-wide evaluation and recommendations are included in the executive summary. Background information on CEPP project goals, objectives, assumptions, and alternatives is included in this section. The following sections describe the evaluation process used for each region.

3 LAKE OKEECHOBEE REGIONAL REPORT

RECOVER System-wide Regional Evaluation

Central Everglades Planning Project

Steve Schubert, Andy Rodusky, (RECOVER Lake Okeechobee Regional Coordinators)
And Bruce Sharfstein (SFWMD)

3.1 Executive Summary

To promote understanding for stakeholders, managers, and Central Everglades Planning Project (CEPP) Project Delivery Team (PDT) members, here are the key findings:

1. Two of four performance measures (Extreme High Lake Stage and Extreme Low Lake Stage) showed no difference between the Existing Condition Baseline (ECB), Future With Project (ALTS), and Future Without Project (FWO) simulations.
2. One performance measure (Above Stage Envelope Score) indicated the simulated FWO was better than the simulated ALTS or ECB, but one performance measure (Below Stage Envelope Score) indicated the opposite. The above stage envelope score is considered to have more potential to be ecologically damaging of the two scenarios for the lake.
3. Based on the daily time series, the simulated runs for the ECB, FWO, and ALTS were very similar much of the time;
4. However, for approximately 5 percent of the period of simulation there were seven separate multiple-day events of such duration (ranging from 79 to 250 consecutive days) above 15.0 feet lake stage where we would expect some negative effects from the ALTS to the aquatic vegetation habitat (including macroinvertebrates and fish that utilize the vegetation) in the lake. Temporary reductions in shallow-water foraging habitat for shorebirds and short-legged wading birds could also occur during these times.

3.2 Introduction

This report evaluates model predictions of freshwater flows for the northern component of the Central Everglades Planning Project (CEPP), also known as the Flow Equalization Basin (ALTS) "north of the red line," and compares them to a "future without project" (FWO) condition and the "existing condition baseline" (ECB) for Lake Okeechobee. The performance measures used in this evaluation include excessive high lake stage (>17.0 feet), excessive low lake stage (< 10.0 feet), and stage envelope (12.5 feet to 15.5 feet) which are all described in the Lake Stage Lake Okeechobee Performance Measure document (RECOVER 2007a) available on the RECOVER web pages at http://www.evergladesplan.org/pm/recover/perf_low.aspx. Also included are evaluations of flood protection criteria and minimum water level and duration. We did not evaluate the mean annual flood control releases metric for the Caloosahatchee River, C-44 Canal, or L-8 Canals because those data were not provided.

3.3 Performance Measures

The Comprehensive Everglades Restoration Plan (CERP) goals for Lake Okeechobee are no frequent or prolonged (2 to 4 months) departures of lake stage outside of the prescribed lake stage envelope and only rare occurrences of the extreme high and low stage events. To meet the specific water demands of the CEPP, we anticipated that the lake stages would need to be higher on average, so our evaluation was based more on the CEPP goal of "do no harm."

Published research, summarized in Havens (2002), documented the benefits of seasonally variable water levels for the plant and animal communities of Lake Okeechobee. The ideal water levels ranged from 12.5 feet National Geodetic Vertical Datum (NGVD) during the months of June-July to 15.5 feet NGVD during the months of November-January. Falling water levels in late winter to spring benefit wading birds by concentrating prey resources in the littoral zone where those birds forage (Smith et al. 1995). Water levels near 12.5 feet NGVD benefit submerged plants and bulrush by providing optimal light levels for photosynthesis in the summer months (Havens et al. 2004). Variation in the prescribed range results in annual flooding and drying of upslope areas of the littoral zone, which favors development of a diverse emergent plant community (Richardson and Hamouda 1995, Keddy and Fraser 2000).

Subsequent to the development of these performance measures, observations indicated that 15.0 feet might be better than 15.5 feet, especially following the implementation of the Lake Okeechobee Regulation Schedule (LORS) in April 2008. At 15.0 feet, there is minimal vertical stacking of water in the northwest marsh and inundation is very similar to pre-levee conditions for the short hydro-period marsh and prairie in this area. Also at 15.0 feet, there are approximately 1,000 acres of foraging habitat for short-legged wading birds (i.e., 1 to 6 inches deep). However, at 15.5 feet, the littoral zone is too deep for these birds, and there is almost no exposed lake bottom for shorebirds. The LORS tends to hold lake levels lower than its predecessor schedule (Water Supply and Environment); therefore, when the lake rises above 15.0 feet under LORS, it is potentially more damaging. For example, under lower lake stages, the area around the toe of the levee tends to shift to more upland vegetation, so that when it becomes inundated (at 15.5 feet, or greater) it becomes a source for nutrients and organic carbon as terrestrial vegetation dies, which may also create low dissolved oxygen conditions and fish kills; negative effects which may not be balanced by the eventual development of a wetland vegetation community if the temporal component of inundation is too short.

Research has also been published on the adverse impacts of extreme high and extreme low water levels on the littoral and nearshore areas of Lake Okeechobee (Havens 2002). Extreme high stage, above 17 feet NGVD, allows wind-driven waves to uproot emergent and submergent plants in the littoral and nearshore regions. In addition, high lake stage permits the transport of suspended solids from the open water region, where unconsolidated sediments are thickest, to sand and peat dominated nearshore and littoral regions. Transport of suspended solids to the nearshore and littoral regions reduces water clarity and light penetration, resulting in less submerged aquatic vegetation growth (James and Havens 2005). At extreme high lake stage, the transport of nutrient-rich water from the open water region to the littoral region may increase phytoplankton biomass and algal bloom frequency (RECOVER, 2007b). It may also reduce periphyton biomass, result in a less desirable community structure (e.g., increased cyanobacteria), and induce shifts in plant dominance to more undesirable taxa, such as the expansion of cattail. Overall, high lake stages can result in reduced growth and germination of submerged plants, reduced reproduction of fish, and reduced diversity and increase of pollution-tolerant macroinvertebrates. Detailed research results regarding high stage impacts on the lake's plant and animal communities are in Maceina and Soballe (1990), Havens (1997), and Havens et al. (2001).

Conversely, extreme low stage, below 10 feet NGVD, results in desiccation of the entire littoral zone, the shoreline fringing bulrush zone, and the majority of the nearshore region that supports submerged plants. Extreme low stage also encourages invasive exotic plants such as torpedograss and melaleuca to establish in areas of the littoral zone where they did not formerly occur, displacing native vegetation. Recovery from prolonged low stage events below 10 feet NGVD is slow, requiring multiple years of appropriate stage regime to recover, as documented for submerged plants by Havens et al. (2004), for sport fish such as largemouth bass (Havens et al. 2005) and from field observations from 2007 to present.

3.4 Evaluation

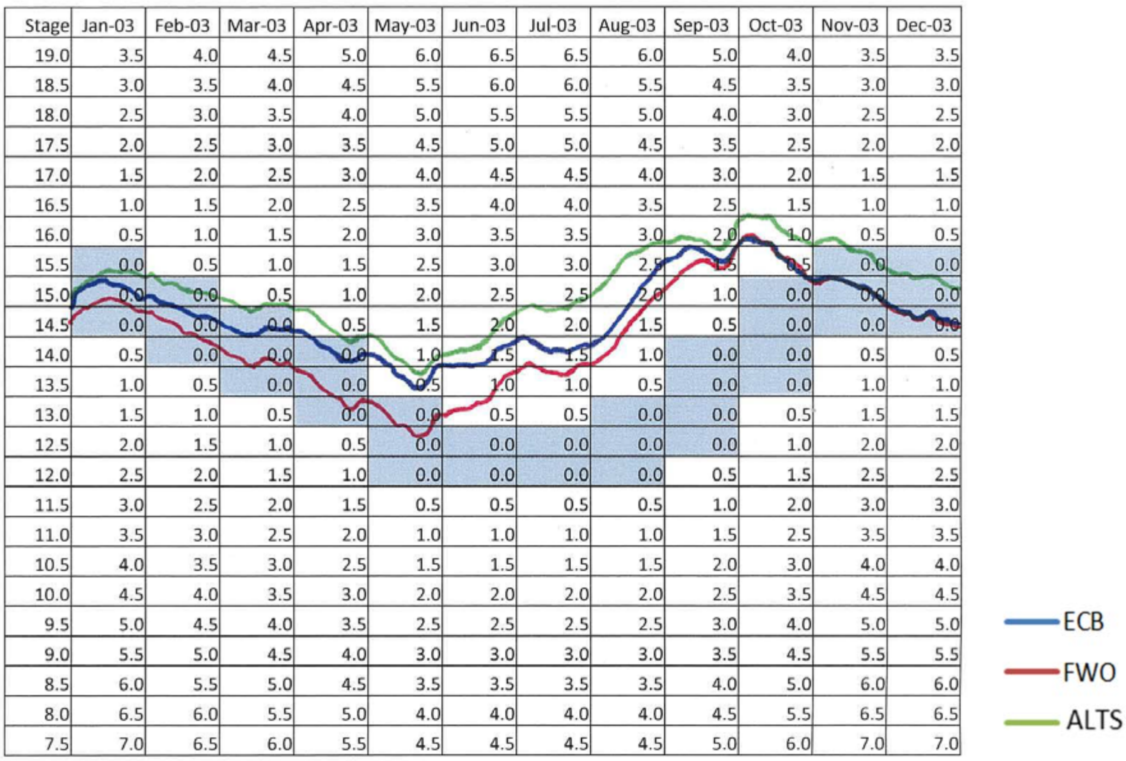
Above Lake Stage Envelope

The above lake stage envelope performance measure evaluates both the magnitude and duration that alternative plans exceed the optimal stage envelope. **Figure 3-1** shows an example of the performance of both alternatives and the existing baseline conditions for calendar year 2003, compared to optimal conditions. Optimal conditions are met when lake levels occur between 12.0 and 15.5 ft as represented in **Figure 3-1**. For the period of simulation, the standardized scores ranged from 82.50 for FWO to 73.48 for ALTS out of a perfect score of 100 (**Figure 3-2**). The value for the ECB was 75.74. Based on this measure the ALTS had the poorest performance.

To better understand the standardized scores, we evaluated years where the greatest differences between hydrographs occurred (**Figure 3-1**). In 2003, the ALTS lake stage was 6 to 12 inches higher than it was for the FWO for the entire year. However, although this performance measure may indicate a difference in lake stage, it did not always translate to a difference in hydrograph score. For example, in simulated January and February 2003, although the modeling indicated the lake was deeper under the ALTS than the FWO, the alternatives for both months were within optimal conditions. Contrast that to simulated June, July, and August 2003, where neither alternative performed optimally, but FWO was ~12 inches lower than ALTS and therefore, received a better overall score.

Below Lake Stage Envelope

The below lake stage envelope performance measure evaluates how many times the alternative plans result in a stage envelope below the optimal level. The standardized score is derived from a combination of the magnitude and duration of exceedances. A perfect score would be 100. The results ranged from 42.41 (ALTS) to 34.29 (FWO) (**Figure 3-3**) indicating that the ALTS performed better than the FWO. The ECB was in between with a score of 40.32.



Stage	Jan-03	Feb-03	Mar-03	Apr-03	May-03	Jun-03	Jul-03	Aug-03	Sep-03	Oct-03	Nov-03	Dec-03
19.0	3.5	4.0	4.5	5.0	6.0	6.5	6.5	6.0	5.0	4.0	3.5	3.5
18.5	3.0	3.5	4.0	4.5	5.5	6.0	6.0	5.5	4.5	3.5	3.0	3.0
18.0	2.5	3.0	3.5	4.0	5.0	5.5	5.5	5.0	4.0	3.0	2.5	2.5
17.5	2.0	2.5	3.0	3.5	4.5	5.0	5.0	4.5	3.5	2.5	2.0	2.0
17.0	1.5	2.0	2.5	3.0	4.0	4.5	4.5	4.0	3.0	2.0	1.5	1.5
16.5	1.0	1.5	2.0	2.5	3.5	4.0	4.0	3.5	2.5	1.5	1.0	1.0
16.0	0.5	1.0	1.5	2.0	3.0	3.5	3.5	3.0	2.0	1.0	0.5	0.5
15.5	0.0	0.5	1.0	1.5	2.5	3.0	3.0	2.5	1.5	0.5	0.0	0.0
15.0	0.0	0.0	0.5	1.0	2.0	2.5	2.5	2.0	1.0	0.0	0.0	0.0
14.5	0.0	0.0	0.0	0.5	1.5	2.0	2.0	1.5	0.5	0.0	0.0	0.0
14.0	0.5	0.0	0.0	0.0	1.0	1.5	1.5	1.0	0.0	0.0	0.5	0.5
13.5	1.0	0.5	0.0	0.0	0.5	1.0	1.0	0.5	0.0	0.0	1.0	1.0
13.0	1.5	1.0	0.5	0.0	0.0	0.5	0.5	0.0	0.0	0.5	1.5	1.5
12.5	2.0	1.5	1.0	0.5	0.0	0.0	0.0	0.0	0.0	1.0	2.0	2.0
12.0	2.5	2.0	1.5	1.0	0.0	0.0	0.0	0.0	0.5	1.5	2.5	2.5
11.5	3.0	2.5	2.0	1.5	0.5	0.5	0.5	0.5	1.0	2.0	3.0	3.0
11.0	3.5	3.0	2.5	2.0	1.0	1.0	1.0	1.0	1.5	2.5	3.5	3.5
10.5	4.0	3.5	3.0	2.5	1.5	1.5	1.5	1.5	2.0	3.0	4.0	4.0
10.0	4.5	4.0	3.5	3.0	2.0	2.0	2.0	2.0	2.5	3.5	4.5	4.5
9.5	5.0	4.5	4.0	3.5	2.5	2.5	2.5	2.5	3.0	4.0	5.0	5.0
9.0	5.5	5.0	4.5	4.0	3.0	3.0	3.0	3.0	3.5	4.5	5.5	5.5
8.5	6.0	5.5	5.0	4.5	3.5	3.5	3.5	3.5	4.0	5.0	6.0	6.0
8.0	6.5	6.0	5.5	5.0	4.0	4.0	4.0	4.0	4.5	5.5	6.5	6.5
7.5	7.0	6.5	6.0	5.5	4.5	4.5	4.5	4.5	5.0	6.0	7.0	7.0

Figure 3-1. Lake Okeechobee stage duration curve for 2003 under Existing Conditions (ECB), Future Without Project (FWO), and Future With Project (ALTS). Optimal conditions are represented by the blue band between 15.5 and 12.0 feet.

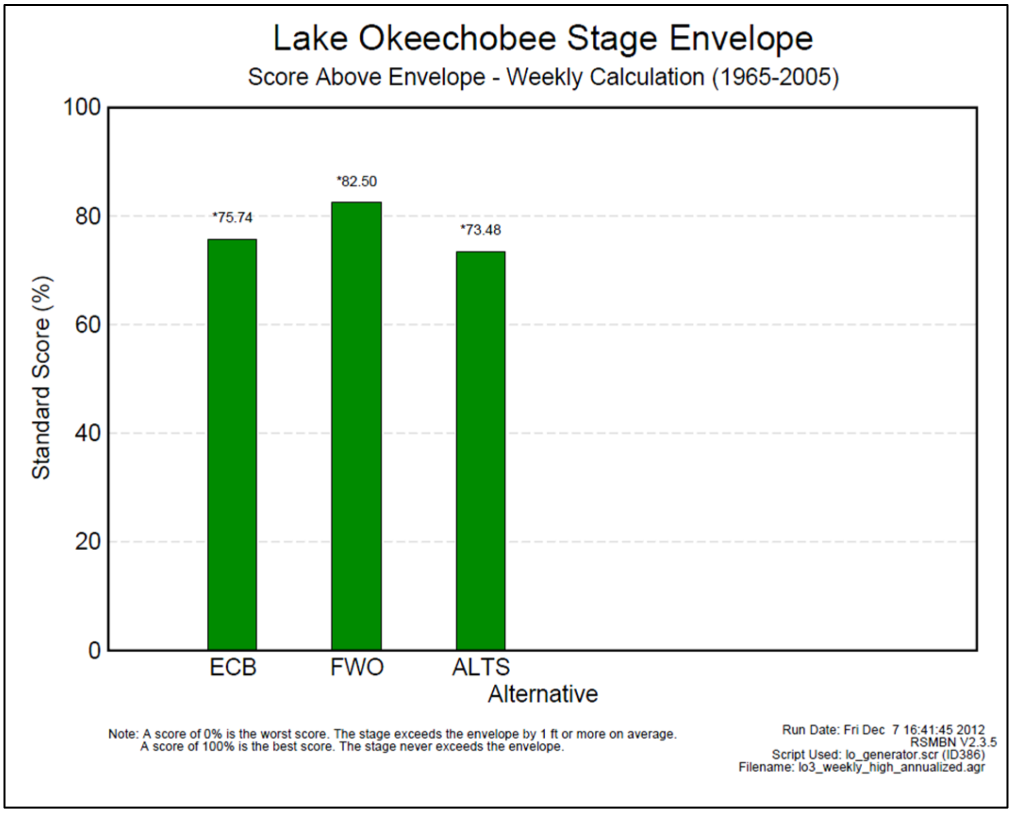


Figure 3-2. Lake Okeechobee above stage envelope scores.

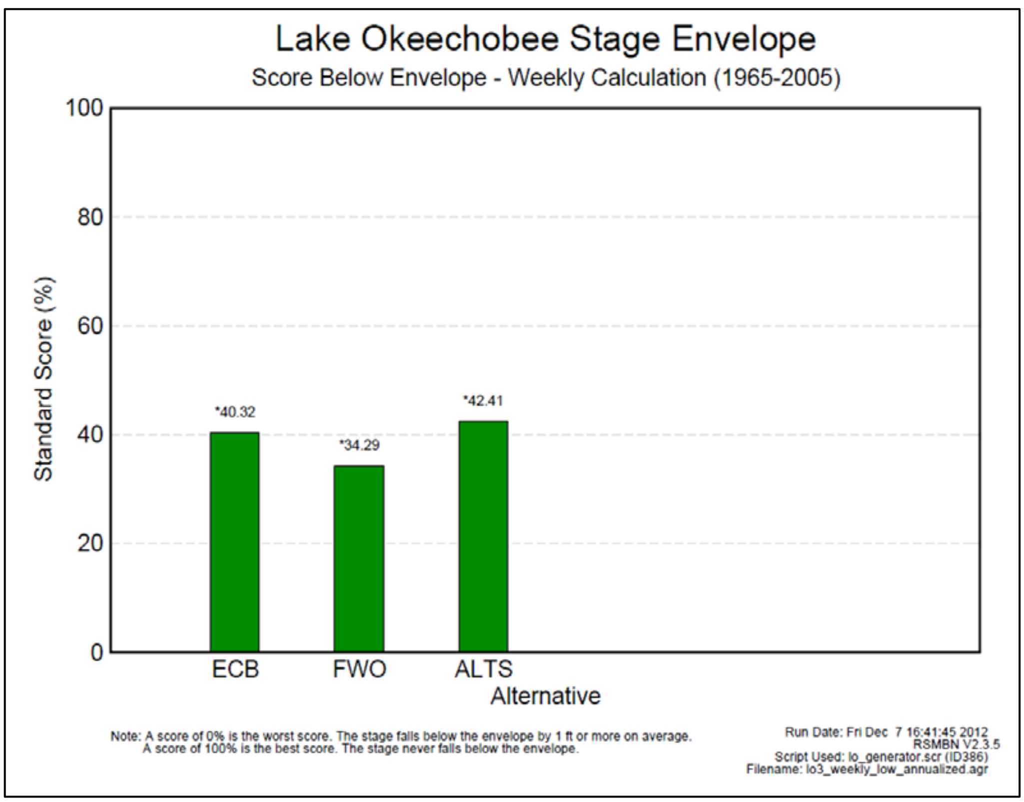


Figure 3-3. Lake Okeechobee below stage envelope scores.

Above Extreme High Lake Stage

The above extreme high lake stage performance measure evaluates the amount of time lake stage is in excess of 17 feet NGVD. The scores ranged from 99.11 for FWO and ECB to 97.78 for ALTS (**Figure 3-4**). These results indicated no significant difference between alternatives.

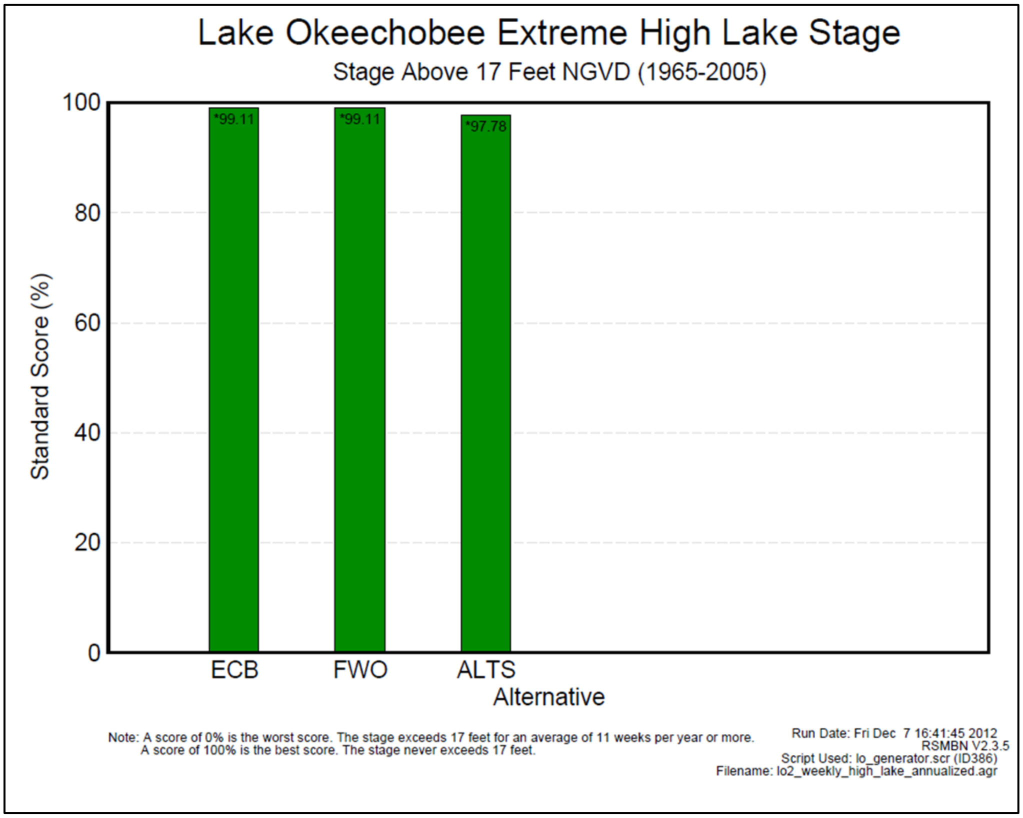


Figure 3-4. Lake Okeechobee extreme high lake stage scores.

Below Extreme Low Lake Stage

The below extreme low lake stage performance measure evaluates the amount of time lake stage is below 10 feet NGVD. The scores ranged from 87.48 (ALTS) to 86.02 (FWO) (**Figure 3-5**). Because of uncertainty in model simulations, it is difficult to define if these are significantly different outcomes statistically or environmentally.

Stage Duration Curve

Figure 3-6 shows the stage duration curves for the FWO, ALTS, and ECB. The ideal curve would be very flat between lake stages 12.5 to 15.0 feet and steep outside this range. The curve showed a similar pattern for FWO, ALTS, and ECB when the lake was below 12.6 feet. This might be expected given the proposed operation of the CEPP to stop lake releases (under ALTS) if lake levels drop to 12.6 feet (in effect from January 1 to August 31).

For the remainder of the curve the ALTS holds the lake higher than the FWO. This was also expected because modelers held the lake higher to offset the additional water demand of the CEPP, which calls for sending an annual average 200,000 acre-feet south to the Everglades. For the critical time where the preferred lake stage is between 12.5 and 15.5 feet, the ALTS performed better by holding the lake in that range for slightly more time (this was also reflected in the "score below envelope" metric in **Figure 3-3**). At damaging high stages (15.5 to 17.0 feet), the ALTS performs slightly worse by holding lake stage higher for a longer amount of time.

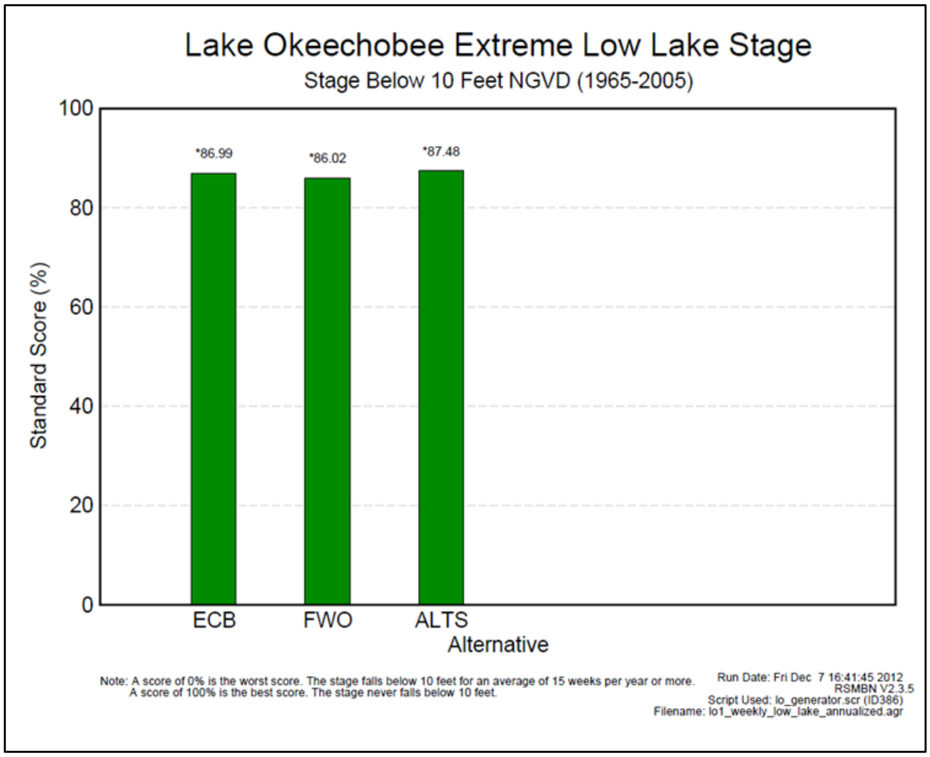


Figure 3-5. Lake Okeechobee Extreme Low Lake Stage Scores.

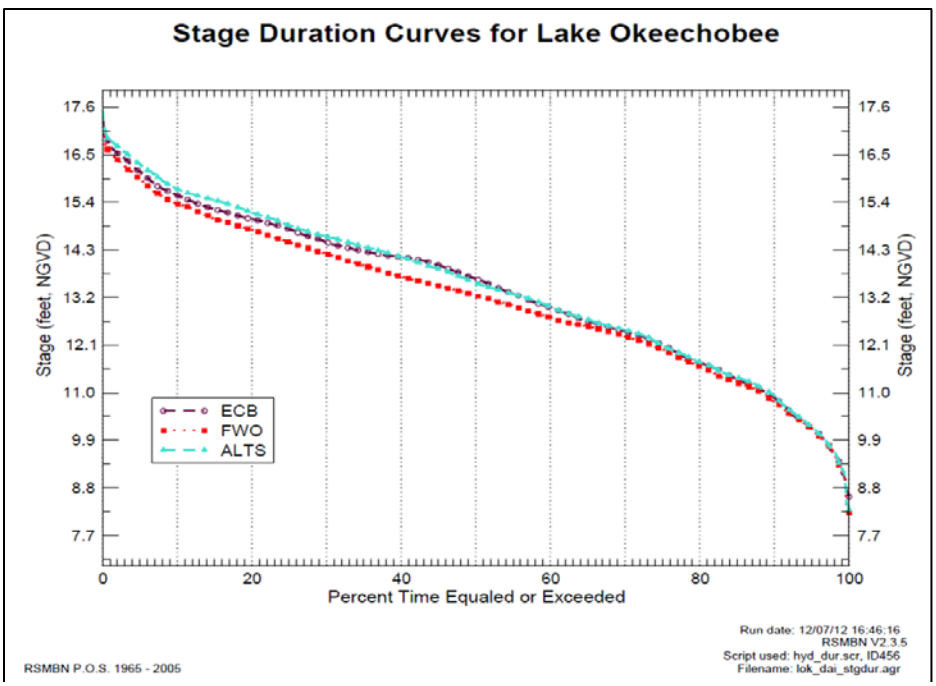


Figure 3-6. Lake Okeechobee Stage Duration Curve.

Flood Protection Criteria

The flood protection criteria evaluate the number of days the lake stage is above 16.5 feet NGVD from August 1 to September 15 as well as the maximum water levels in the 41-year period of simulation. While both alternatives exceeded the 16.5 feet stage at various times of the year, only the ALTS exceeded it (for seven days in September 1995; maximum stage = 16.52 feet) during the appropriate time of year. During this period, the FWO maximum simulated stage was 16.14 feet. We do not believe this to be a substantial difference for this short duration.

The maximum water levels during the entire period of simulation for the ECB and both alternatives (achieved on April 1, 1970) were as follows: 17.54 feet (ECB), 17.64 feet (ALTS), and 17.50 feet (FWO). For these criteria, the simulated FWO performed better than the ALTS numerically, although it is not apparent that this 0.14 foot difference is meaningful.

Minimum Water Level and Duration Measure

The minimum water level and duration measure compares the number of times that the simulated water level was below 11.0 feet NGVD for more than 80 consecutive days in the 41-year simulation. Note that this is different from the revised MFL (minimum flows and levels) performance measure as it is purely hydrologic and does not take into account the legal definition of how MFL exceedances and violations are counted. The ECB, FWO, and ALT exceeded this measure six times. For the simulated 1974, 1977, and 1981 events, the numbers of days between the ECB and two alternatives were similar. However, in 1989, the ECB and ALTS simulations were comparable (151 and 148 days, respectively), and outperformed the FWO (which was below 11.0 feet for 191 days). In 1990, the ALTS (164 days) performed better than both the ECB (188 days) and the FWO (189 days). In 2001, the ECB (229 days) outperformed both the FWO (272 days) and the ALTS (263 days). We expected that the ALTS would perform better under this metric because the lake operations were changed under the ALTS simulation to hold lake stages higher when possible to make water more available to the CEPP. As recent data have indicated (actual conditions 2005 to 2012), a lower lake stage is not as harmful to the Lake's ecology as high water stages (RECOVER 2009, 2012). Therefore, this performance measure could be refined to enable an actual determination of minimum water level violations, which would include an *x* times in *y* years component. As it stands now, the ECB, FWO, and ALTS had the same number of exceedances, but the ALTS had fewer days below the threshold within two of the six events (i.e., performed slightly better).

3.5 Other Information Sources

Ranking of Alternatives

We weighted the scores for each alternative by performance measure as follows:

- Standard Score Above 17 feet NGVD (50%)
- Standard Score Below 10 feet NGVD (25%)
- Standard Score Above Stage Envelope (15%)
- Standard Score Below Stage Envelope (10%)

We based our rationale for weighting on the assumption that water levels above 17.0 feet are the most ecologically damaging. Water levels less than 10.0 feet are also ecologically damaging, but less so, therefore, they were weighted less. Similarly, the standard scores for both above and below the stage envelope were weighted the least. We then summarized the weighted averages (**Table 3-1**).

We did not include scores for Flood Protection Criteria or the Minimum Water Level and Duration Measure because the differences between alternatives were either statistically negligible or ecologically meaningless. Numerically, the FWO performed the best with a score of 86.86, but due to the sensitivities and uncertainties of the modeling and the performance measures, this analysis shows no difference between the ECB, FWO, or alternatives.

Table 3-1. Individual scores and weighted averages for both CEPP alternatives and the existing condition baseline for each Lake Okeechobee performance measure [scores could range from 0 (worst) to 100 (best)].

Performance measure	**ECB**	**Alternatives**	**FWO**
Extreme high (above 17 feet)	99.11	97.78	99.11
Extreme low (below 10 feet)	86.99	87.48	86.02
Stage envelope Above Below	75.74 40.32	73.48 42.41	82.50 34.29
Weighted Average	**86.70**	**86.02**	**86.86**

Additional Analysis of the Daily Time Series

Due to a general lack of differences between the performance measures of either alternative, we examined the daily time series over the period of simulation (1965-2005) in order to assess whether or not the CEPP, as proposed, had an effect on water stages in Lake Okeechobee. We used 15.0 feet rather than 15.5 feet as our benchmark for ecological damage due to recent observations as discussed earlier in Section 3.3. **Figure 3-7** through **Figure 3-14** show the daily, simulated hydrographs for the ECB, FWO, and ALTS.

We identified seven events where the simulated ALTS hydrograph performed worse (*i.e.,* potentially more ecologically damaging because the stage was greater for a substantial amount of time) than the simulated FWO. It is difficult to say whether substantial ecological damage would occur if these simulations reflected "real world" conditions because we do not have evaluation tools that are precise enough to parse out the differences. We can infer from on-going vegetation studies in Lake Okeechobee that the following events have, at least, the potential to negatively affect submerged aquatic vegetation; however, because it may take 6 months to 3 or 4 years for vegetation shifts to result from differing conditions, and because of other compounding factors (turbidity, nutrients, and storms) we cannot offer better conclusions. The seven events are as follows.

From July 20, 1968 to January 13, 1969 (178 days), the ALTS was above the 15.0 feet threshold, but the FWO was not. During this period, there were 44 days when the ALTS was 6 inches to 10 inches higher than the FWO and 117 days of difference greater than 10 inches (maximum stage was 16.06 feet) (**Figure 3-7**).

The ALTS simulation was also greater than 15.0 feet for 222 days (August 25, 1978 to April 3, 1979), while the FWO simulation exceeded this stage for only 98 days during this period. Furthermore, the ALTS exhibited a 6-inch to 8.3-inch difference for 88 days over the FWO (**Figure 3-9**).

The ALTS simulation was greater than 15.0 feet for 109 days (October 11, 1983 to January 27, 1984), while the FWO simulation did not exceed 15.0 feet (range = 14.39 to 14.87 feet). Additionally, the ALTS simulation was 6 inches to 8.63 inches higher than the FWO (**Figure 3-10**).

From August 28, 1991 to December 11, 1991 (106 days), the ALTS simulation was again greater than 15.0 feet (maximum = 15.62 feet). Over this same period, the FWO simulation was greater than 15.0 feet for 50 days (maximum = 15.20 feet). The alternatives were 6 inches to 8.4 inches higher than the FWO for 46 days (**Figure 3-12**).

The ALTS exceeded 15.0 feet from August 29, 1992 to May 5, 1993 (250 days; maximum 15.88 feet), while the FWO exceeded 15.0 feet for only 84 days (maximum = 15.39 feet). Additionally, the ALTS simulation was 6 inches to 9.77 inches higher than the FWO for 199 days during that period (**Figure 3-12**).

From December 23, 2002 to March 11, 2003 (79 days), the ALTS simulation was again greater than 15.0 feet. Over this same period, the FWO simulation was greater than 15.0 feet for only 10 days (maximum = 15.05 feet). The ALTS was 6 inches to 11.65 inches higher than the FWO (**Figure 3-14**).

From July 24, 2003 to January 12, 2004 (173 days), the ALTS simulation was greater than 15.0 feet and achieved a maximum elevation of 16.48 feet. Over this same period, the FWO simulation was greater than 15.0 feet for 100 days (maximum = 16.22 feet). The ALTS was 6 inches to 10 inches higher than the FWO for 78 days and 10 inches to 15.16 inches higher than the FWO for an additional 43 days (**Figure 3-14**).

We also identified times when the 17.0 feet threshold was exceeded by both the ALTS and the FWO (although for less time for the FWO). For example, from March 27, 1970 to April 12, 1970, the ALTS simulation exceeded the 17.0 feet threshold for 17 days (maximum stage = 17.64 feet) (**Figure 3-7**). The FWO exceeded 17.0 feet during this same period for 15 days (maximum stage = 17.50 feet). A similar event happened from October 18, 1995 to November 7, 1995 (**Figure 3-12**). Conversely, from November 2, 2005 to November 17, 2005, the ALTS exceeded 17.0 feet (maximum = 17.24 feet), while the FWO only reached a maximum elevation of 16.69 feet (**Figure 3-14**). None of these events, even though they exceeded 17.0 feet, indicated a measurable ecological difference between the ALTS and FWO simulations. In essence, both alternatives performed poorly and no additional substantial ecological damage would likely have occurred under simulated ALTS conditions (when compared to FWO conditions) during these periods.

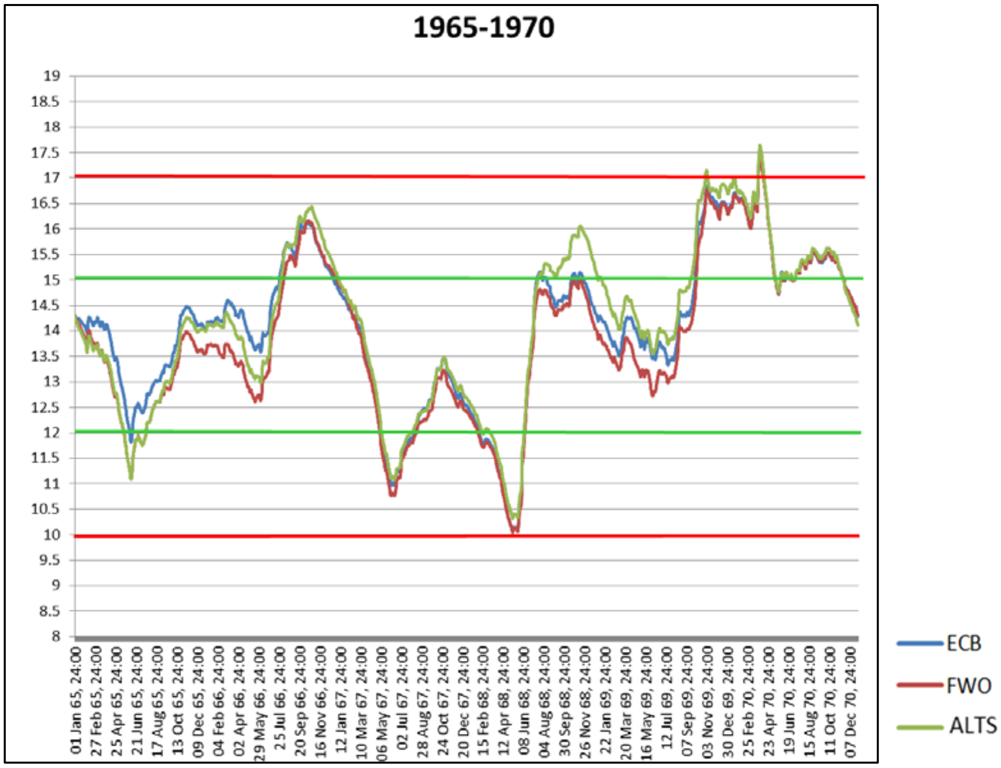


Figure 3-7. Daily Time Series Stage Hydrographs for Lake Okeechobee as simulated for the ECB, ALTS, and FWO from 1965 to 1970.

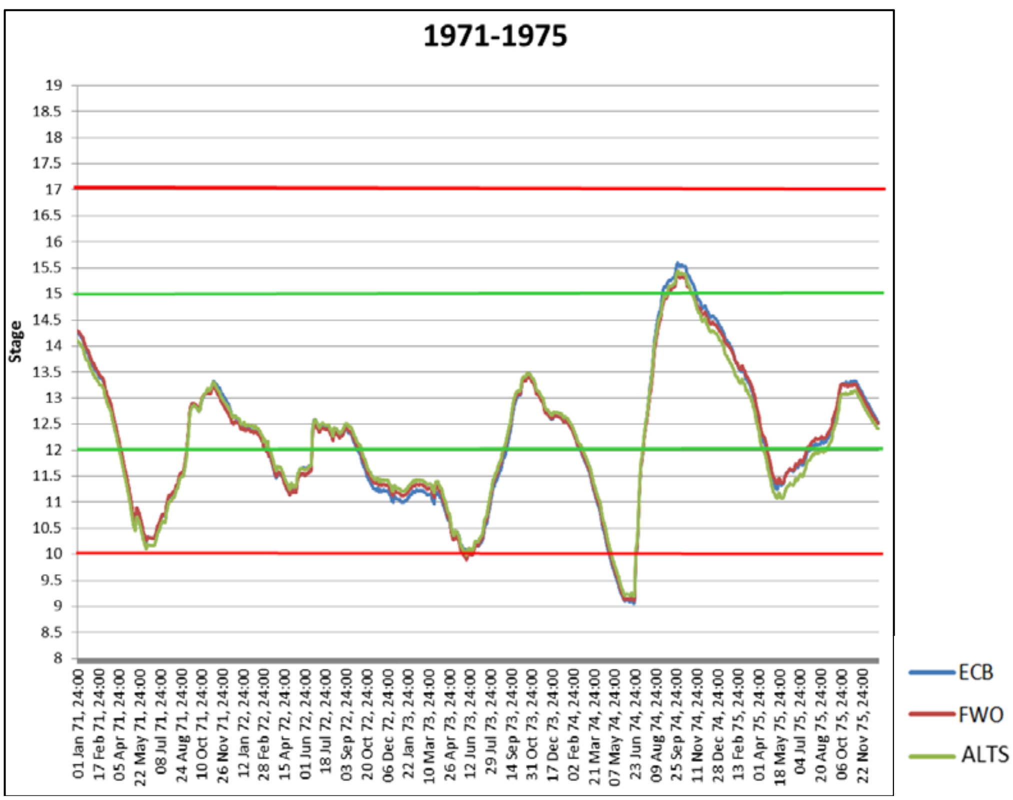


Figure 3-8. Daily Time Series Stage Hydrographs for Lake Okeechobee as simulated for the ECB, ALTS, and FWO from 1971 to 1975.

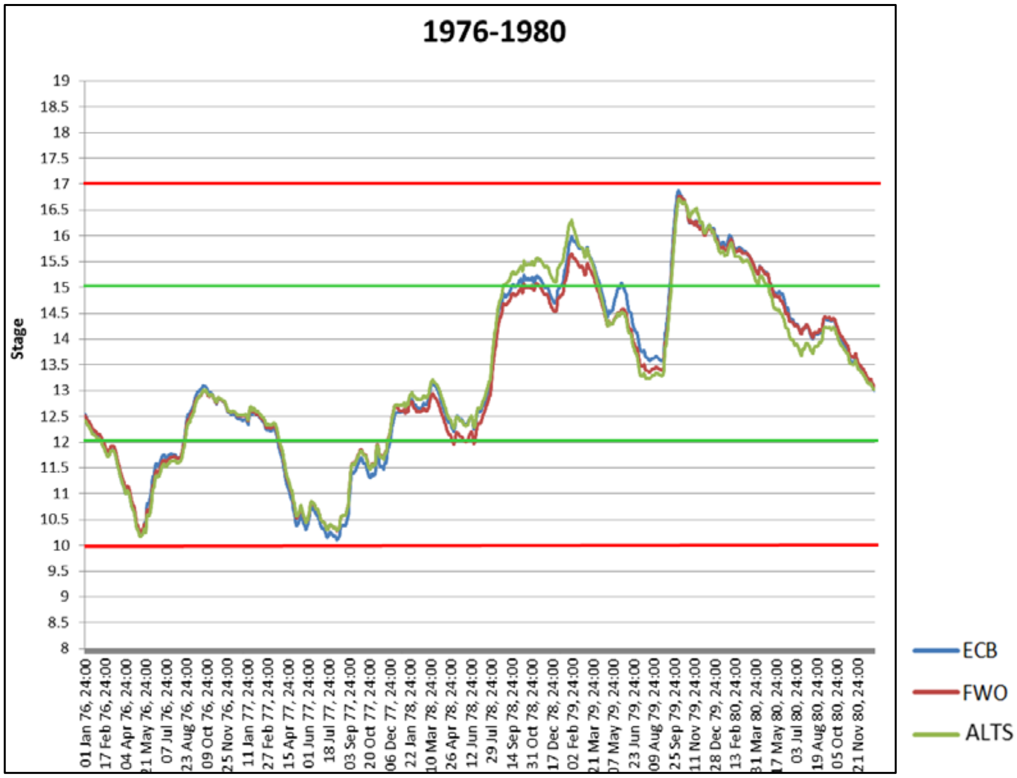


Figure 3-9. Daily Time Series Stage Hydrographs for Lake Okeechobee as simulated for the ECB, ALTS, and FWO from 1976 to 1980.

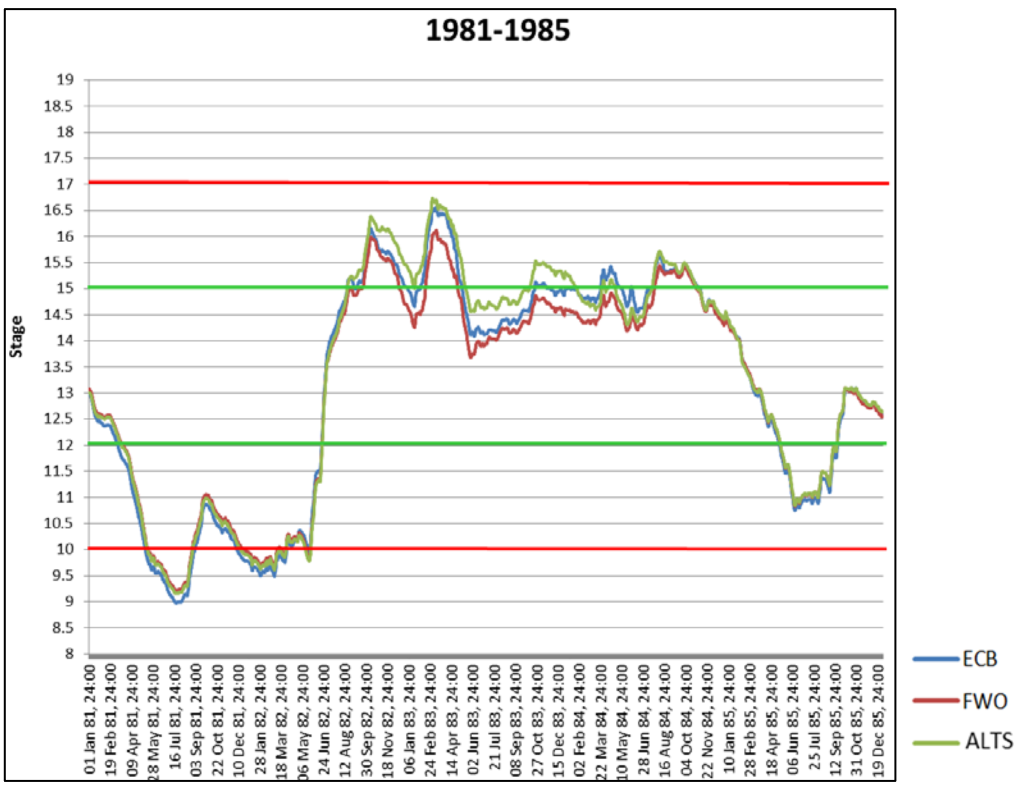


Figure 3-10. Daily Time Series Stage Hydrographs for Lake Okeechobee as simulated for the ECB, ALTS, and FWO from 1981 to 1985.

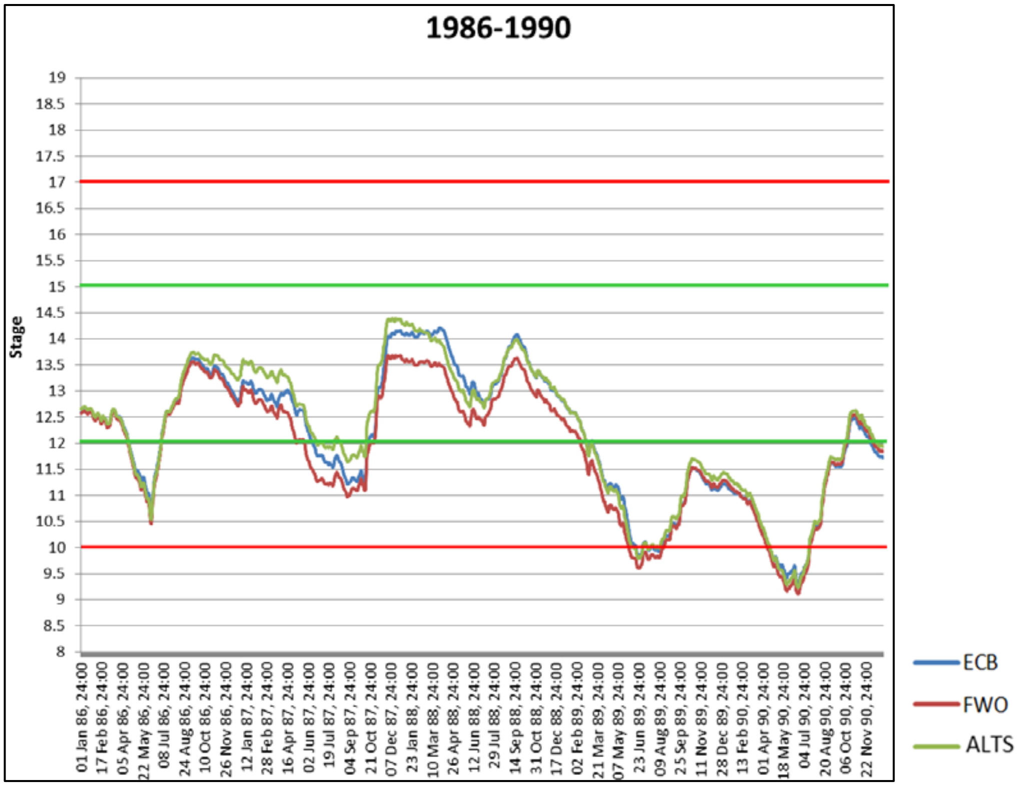


Figure 3-11. Daily Time Series Stage Hydrographs for Lake Okeechobee as simulated for the ECB, ALTS, and FWO from 1986 to 1990.

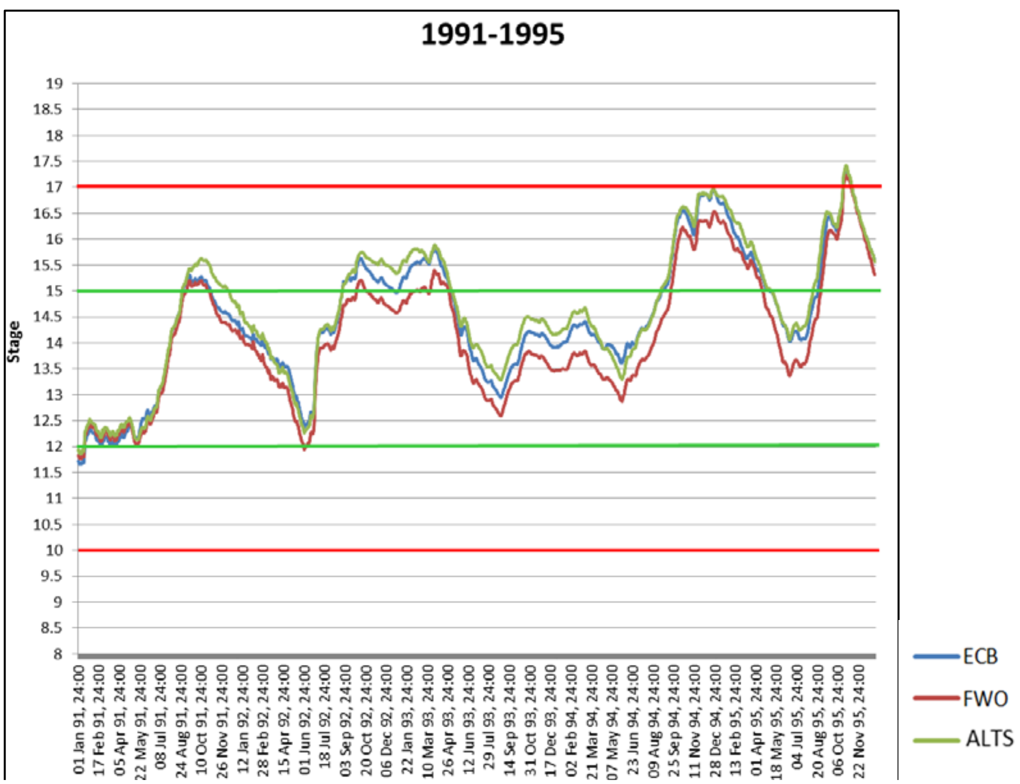


Figure 3-12. Daily Time Series Stage Hydrographs for Lake Okeechobee as simulated for the ECB, ALTS, and FWO from 1991 to 1995.

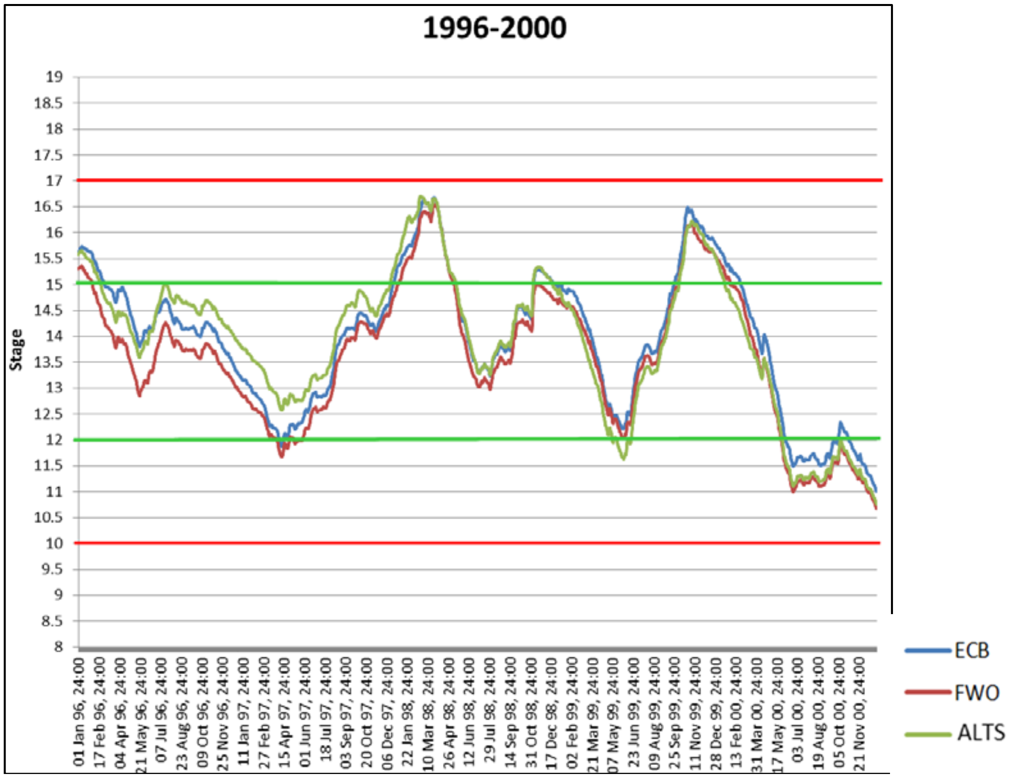


Figure 3-13. Daily Time Series Stage Hydrographs for Lake Okeechobee as simulated for the ECB, ALTS, and FWO from 1996 to 2000.

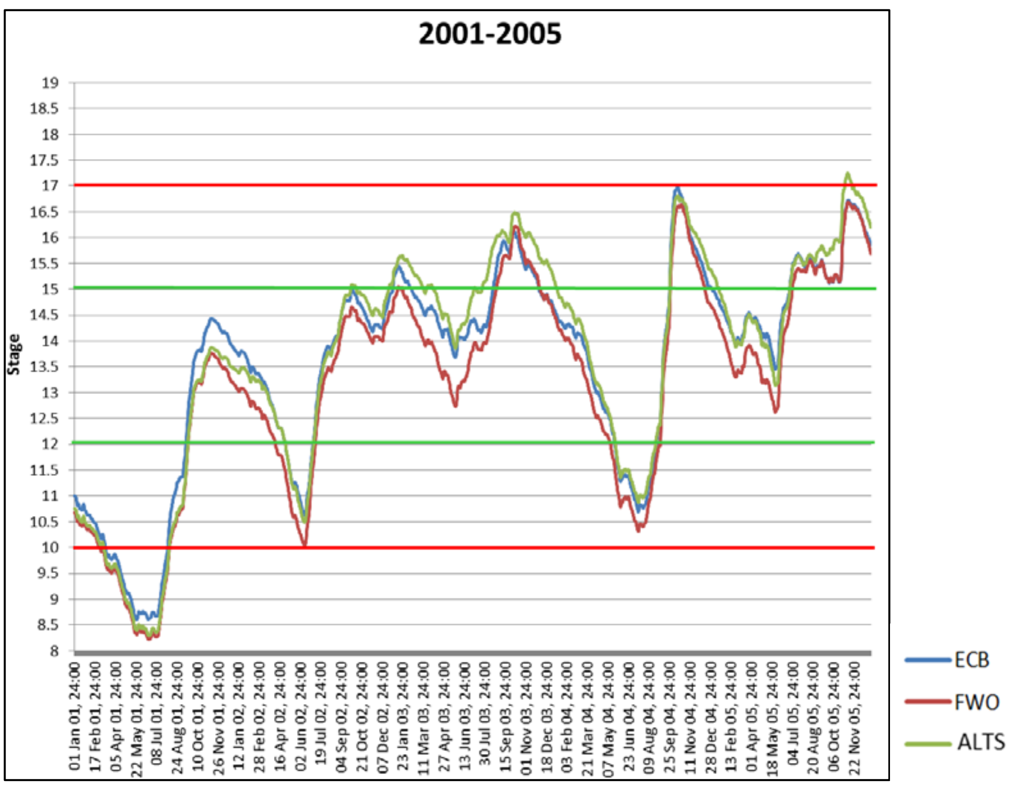


Figure 3-14. Daily Time Series Stage Hydrographs for Lake Okeechobee as simulated for the ECB, ALTS, and FWO from 2001 to 2005.

While the previous discussion identified events where the ALTS may have performed worse than the FWO, there was at least one event where the ALTS may have performed better. On May 25, 1987, the simulated FWO dropped below 12.0 feet (the low side of the preferred stage envelope), and stayed below 12.0 feet until October 22, 1987 (150 days; minimum stage = 10.97 feet). The simulated ALTS dropped below 12 feet for 91 days (minimum stage = 11.64 feet) (**Figure 3-11**). Under these conditions, more of the littoral zone would have been flooded under the ALTS. For example, at 12.0 feet, approximately 26,000 acres of littoral zone are flooded but at 11.5 and 11.0 feet approximately 17,000 and 6,000 acres, respectively, are flooded. Periodic drying of the littoral zone may be beneficial to lake ecology through oxidation of undesirable organic soils (i.e., muck), but prolonged desiccation can negatively affect apple snail survival and cause unwanted shifts from aquatic plant to upland plant species. The duration of this simulated event could have affected native apple snails. According to Darby (2006), adult apple snails show the following desiccation tolerances: a 3-month dry-out will kill 21 percent of the population; a 4-month dry-out will kill 50 percent of the population; and a 4.5-month dry-out will kill 63 percent of the population. Juvenile snails have even less tolerance to desiccation -- for example, a 3-month dry-out will kill 40 percent a population of six-week old apple snails (10-15 mm in size). The simulated FWO was between 11.0 and 11.5 feet for 4 months.

3.6 Summary and Conclusion

Throughout the period of simulation, there were times when there was little or no difference between the ALTS and FWO (**Figure 3-8**). Other times (simulated 2003 in **Figure 3-14**); the potential for ecological differences was greater. Two of the performance measures (extreme low and extreme high stage) indicated no difference over the period of simulation. For the Above Stage Envelope performance measure, the ALTS did not perform as well as the FWO, but for the Below Stage Envelope performance measure, the ALTS performed better than the FWO. This was expected because the changes to the lake's operational rules for the ALTS simulation required the lake to be held higher to meet the added ALTS water demand. It is difficult to predict "real world" ecological differences based on simulated hydrographs, primarily because operational changes can be tweaked almost infinitely (under both simulated and actual conditions). For example, the lake stage was held higher under ALTS to provide more water for the CEPP. Lake stages could potentially be held higher to provide dry season flow benefits to the Caloosahatchee Estuary. The "devil is in the details" related to operational rules that no one knows will be in effect when the project is ready to be operational. Notwithstanding these unknowns, it does seem likely based on the scores for the Above Stage Envelope performance measure that aquatic vegetation would be more impacted under ALTS conditions because high lake stage is thought to be more damaging to the SAV and emergent plant communities compared to low lake stages.

To further test the expectation that the CEPP should "do no harm" to ecological conditions in Lake Okeechobee, the daily time series for specific occurrences where differences were indicated were evaluated. Based on analysis of seven discrete events, the ALTS performed slightly worse for Lake Okeechobee than the FWO. This was manifested in the simulations as higher lake stages (above 15.0 feet NGVD) for a greater amount of time. For example, analysis of these events identified 1,117 total days where the ALTS was above 15.0 feet but the concurrent FWO hydrograph was above 15.0 feet for only 342 days. This difference appears small when you consider the entire number of days in the period of simulation (14,975 days); however, also it should be noted that "rare" or "extreme" events (e.g., droughts, hurricanes, tropical storms, etc) can cause lasting negative effects on the lake. And while these simulated hydrographs may not rise to that level of severity, it is not possible to conclude that multi-year negative effects would not result. This is primarily because it can take up to 3 or 4 years for aquatic vegetation habitat to recover from effects of unsuitable hydrology or water quality in Lake

Okeechobee. An additional biological response to these simulated events could be temporary loss of shorebird and short-legged wading bird foraging habitat (especially during fall-winter migrations). Of the seven events identified, the simulated 1968, 1983, and 1992 events had the largest potential for harm to lake ecology. An event in the summer of 1987 was also identified where the simulated ALTS performed better by keeping more of the littoral zone inundated than did the FWO.

Continued research is necessary to better understand the specific water depth and duration thresholds associated with potential declines in habitat, ecosystem health, and water quality. The current performance measures are based on an assumption of linear increase in risk of ecological damage between the optimal conditions and the most severe condition, which is the most conservative approach to take until there are data to support a more complex relationship. Adaptively managing lake stages can promote lake health and maximize the lake's contribution to the estuaries and Greater Everglades marshes. Refinement of the performance measures and their index models would in turn assist future development and refinement of lake schedules.

3.7 References

Darby, P. 2006. Personal Communication. Biologist. Video teleconference presentation on November 28, 2006. University of West Florida; Pensacola, Florida.

Havens, K.E. 1997. Water levels and total phosphorus in Lake Okeechobee. Lake and Reservoir Management, 13, 16-25

Havens, K.E., K.-R. Jin, A.J. Rodusky, B. Sharfstein, M.A. Brady, T.L. East, N. Iricanin, R.T. James, M.C. Harwell, and A.D. Steinman. 2001. Hurricane effects on a shallow lake ecosystem and its response to a controlled manipulation of water level. The Scientific World 1:44-70.

Havens, K.E. 2002. Development and application of hydrologic restoration goals for a large subtropical lake. Lake and Reservoir Management 18:285-292.

Havens, K.E., B. Sharfstein, M.A. Brady, T.L. East, M.C. Harwell, R.P. Maki and A.J.Rodusky. 2004. Recovery of submerged plants from high water stress in a large subtropical lake in Florida, USA. Aquatic Botany 78:67-82.

Havens, K.E., D. Fox, S. Gornak and C. Hanlon. 2005. Aquatic vegetation and largemouth bass population responses to water-level variations in Lake Okeechobee, Florida (USA). Hydrobiologia 539:225-237.

James, R.T. and K.E. Havens. 2005. Outcomes of extreme water levels on water quality of offshore and nearshore regions in large shallow subtropical lake. Archiv für Hydrobiologie 163:225-239.

Keddy, P. and L.H. Fraser. 2000. Four general principles for the management and conservation of wetlands in large lakes: the role of water levels, nutrients, competitive hierarchies and centrifugal organization. Lake and Reservoir Management 5:177-185.

Maceina, M.J. and D.M. Soballe. 1990. Wind-related limnological variation in Lake Okeechobee, Florida. Lake and Reservoir Management 6(1):93-100.

RECOVER. 2007a. CERP System-wide Performance Measure Documentation Sheet. Lake Okeechobee Performance Measure, Lake Stage. Restoration Coordination and Verification Program c/o U.S. Army Corps of Engineers, Jacksonville, FL, and South Florida Water Management District, West Palm Beach, FL. March 7.

RECOVER. 2007b. 2007 System Status Report. Restoration Coordination and Verification Program c/o U.S. Army Corps of Engineers, Jacksonville, FL, and South Florida Water Management District, West Palm Beach, FL. July 2007.

RECOVER. 2009. 2009 System Status Report. Restoration Coordination and Verification Program c/o U.S. Army Corps of Engineers, Jacksonville, FL, and South Florida Water Management District, West Palm Beach, FL. http://www.evergladesplan.org/pm/ssr_2009/ssr_main.aspx

RECOVER. 2012. In Press. 2012 System Status Report. Restoration Coordination and Verification Program c/o U.S. Army Corps of Engineers, Jacksonville, FL, and South Florida Water Management District, West Palm Beach, FL.

Richardson, J.R. and E. Hamouda. 1995. GIS modeling of hydroperiod, vegetation, and soil nutrient relationships in the Lake Okeechobee marsh ecosystem. Pages 95-115 in N.G. Aumen and R.G. Wetzel (eds), Advances in Limnology. Schweizerbart, Stuttgart, Germany.

Smith, J.P., J.R. Richardson and M.W, Collopy. 1995. Foraging habitat selection among wading birds (Ciconiiformes) at Lake Okeechobee, Florida, in relation to hydrology and vegetative cover. Pages 247-285 in N.G. Aumen and R.G. Wetzel (eds), Advances in Limnology. Schweizerbart, Stuttgart, Germany.

4 NORTHERN ESTUARIES REGIONAL REPORT

RECOVER System-wide Regional Evaluation

Central Everglades Planning Project

Peter Doering, Gretchen Ehlinger, and Liberta Scotto (RECOVER Northern Estuaries Regional Coordinators), Christopher Buzzelli, Zhiqiang Chen, Patti Gorman, and Yongshan Wan (South Florida Water Management District)

4.1 Executive Summary

To promote understanding for stakeholders, managers, and Central Everglades Planning Project Delivery Team members, here are the key findings from the Northern Estuaries evaluations of the CEPP alternatives:

Caloosahatchee River Estuary
In comparing both low flows (less than 450 cfs) and high flows (greater than 2,800 cfs) over the S-79 structure westward, the A-2 Flow Equalization Basin (Central Everglades Planning Project) was not statistically different from the Future Without Project condition but the flow over 2,800 cfs reductions moved in the right direction for improved estuarine health. However, it was statistically better than the Existing Condition Baseline.

St. Lucie River Estuary
In comparing low flow from Lake Okeechobee thru a combination of structures to the St. Lucie River, A-2 Flow Equalization Basin (Central Everglades Planning Project) was statistically different from both the Existing Condition Baseline and Future Without Project. There are a greater number of days when low flow targets are not met with implementation of the CEPP project. This would increase salinity levels in the estuary during extended dry periods resulting in potential stress to mid-estuary oyster populations due to increased predation and disease.

In comparing high flow events to the St. Lucie River, A-2 Flow Equalization Basin (Central Everglades Planning Project) was statistically better than both Existing Condition Baseline and Future Without Project. The number of high flow events were reduced by approximately 3.5 percent (18 months) with the project as compared to Future Without Project.

4.2 Introduction

The magnitude, timing and distribution of freshwater inflow to the St. Lucie River Estuary (SLE), and the Caloosahatchee River Estuary (CRE) have been disrupted by a number of anthropogenic alterations of the landscape. These include over drainage of coastal watersheds and artificial connections to Lake Okeechobee for flood control purposes. Projects included in the Comprehensive Everglades Restoration Plan (CERP) of which the Central Everglades Planning Project (CEPP) is one, are intended to achieve a more ecologically suitable pattern of freshwater inflow to these systems.

This report evaluates the Regional Simulation Model Basins (RSMBN) predictions of freshwater flows to these two estuaries from the northern component of the CEPP, also known as the A-2 Flow Equalization Basin (ALTS). These simulations assume the current Lake Okeechobee Regulation Schedule (2008LORS) is in effect. To assess the effects of the CEPP, output from three modeling scenarios is contrasted. The Existing Condition Baseline (ECB) represents the present configuration and operation of the water management system. The Future Without Project (FWO) scenario simulates a future configuration of the water management system without the CEPP but with a number of other projects that should benefit the overall system. From an estuarine perspective it is important to note that the FWO scenario includes two CERP projects that restore freshwater inflows to the two estuaries: the Indian River Lagoon – South affecting the SLE and the C-43 West Basin Storage Reservoir affecting the CRE. Lastly, the ALTS scenario is essentially the FWO with the addition of selected CEPP components. The evaluation of these three scenarios is based on an assessment of a number of hydrologic and salinity performance measures as well as an analysis of the simulated performance of selected estuarine resources including seagrasses and oysters.

4.3 Performance Measures and Evaluation Approach

The model output for each scenario consists of a 41-year time series (1965–2005) of daily freshwater inflows to each estuary. For the CRE, flows at the Franklin Lock and Dam (S-79) at the head of the estuary were provided. These flows integrate the effects of discharges from Lake Okeechobee (S-77) and the Caloosahatchee River (C-43) basin. For the SLE, model output is a time series of total freshwater inflow. This includes flows at the S-80 structure, which integrates the discharge from Lake Okeechobee (S-308), and the C-44 basin as well as an estimate of inflows from other basins in the watershed.
The Restoration Coordination and Verification Program's (RECOVER's) Northern Estuaries Module Team developed a number of hydrologic and salinity performance measures located at the following web link: http://www.evergladesplan.org/pm/recover/perf_ne.aspx.

Hydrologic Performance Measures

Hydrologic performance measures for the CRE and SLE are based on the frequency distributions of mean monthly (CRE) or mean 14-day freshwater (SLE) inflows in the 41-year period model output. The number of mean monthly or 14-day flows in discrete flow ranges is evaluated. Each range has a finite range of values associated with it. Range categories are defined by the ecological effects that they produce, and represent a gradient of benign to harmful impacts on the estuaries. Simulated alternative conditions with a lower frequency of flows in harmful ranges are considered to cause less damage to estuarine flora and fauna and are considered the better alternative.

4.4 Evaluation

Caloosahatchee River Estuary

The CRE is evaluated based upon the number of mean monthly flows that fell into specified flow classes during the 492 month, 41-year period of record for each simulation scenario (**Table 4-1**). Flows less than 450 cubic feet per second (cfs) are considered harmful since these flow levels allow salt water to intrude, raising salinity above the tolerance limits for communities of submerged aquatic plants (tape grass [*Vallisneria americana*]), in the upper estuary. Flows greater than 2,800 cfs cause mortality of marine seagrasses (shoal grass [*Halodule wrightii*]) and the Eastern oyster (*Crassostrea virginica*) in the lower estuary and at flows greater than 4,500 cfs, seagrasses begin to decline in San Carlos Bay (**Figure 4-1**). RECOVER's review of the CEPP is focused on freshwater discharges from the C-43 canal at the S-79 structure. A CERP goal is to reestablish a salinity range most favorable to juvenile marine fish, shellfish, oysters and submerged aquatic vegetation (SAV) by reducing high volume and minimum discharge events to the estuary.

The CERP system-wide performance measure for Northern Estuaries salinity envelopes targets a mean monthly inflow for the CRE between 450 and 2,800 cfs during all months (RECOVER 2007). For analysis, high flow events were combined into one flow category (greater than 2,800 cfs). A reduction in the number of high flow (damaging) events represents improvement over the base conditions. A reduction in the number of times the flow goes below 450 cfs, which causes salinity in the upper estuary to get too high also represents improvement.

Table 4-1. Mean monthly flow classes for the CRE and the anticipated ecological effects.

Mean Monthly Inflow at S-79	Ecological Response	Ranking Criteria
< 450 cfs	Damage to upper estuary tape grass	Fewer is better
450–2800 cfs	Tolerable range	More is Better
2800–-4500 cfs	Damage to estuary	Fewer is Better
> 4500 cfs	Damage to estuary and bay	Fewer is Better

The distribution of mean monthly flows for the three scenarios is given in **Table 4-2**. Analysis of the data yielded a statistically significant chi-square (X^2=137.6, df=4, p<0.001). Additional comparisons indicated that ALTS and FWO were statistically different from ECB (X^2 > 80, df = 2, p < 0.001 in both cases), while FWO and ALTS were similar (X^2=1.35, df=2, p=0.509).

Table 4-2. **Distribution of S-79 mean monthly flows over a simulated 41-year period of record.**

Distribution of Mean Monthly Flows at S-79			
Mean Monthly Inflow at S-79	CEPP Scenario		
	ECB	FWO	ALTS
< 450 cfs	116	27	26
450–2800 cfs	282	384	398
> 2,800 cfs	94	81	68

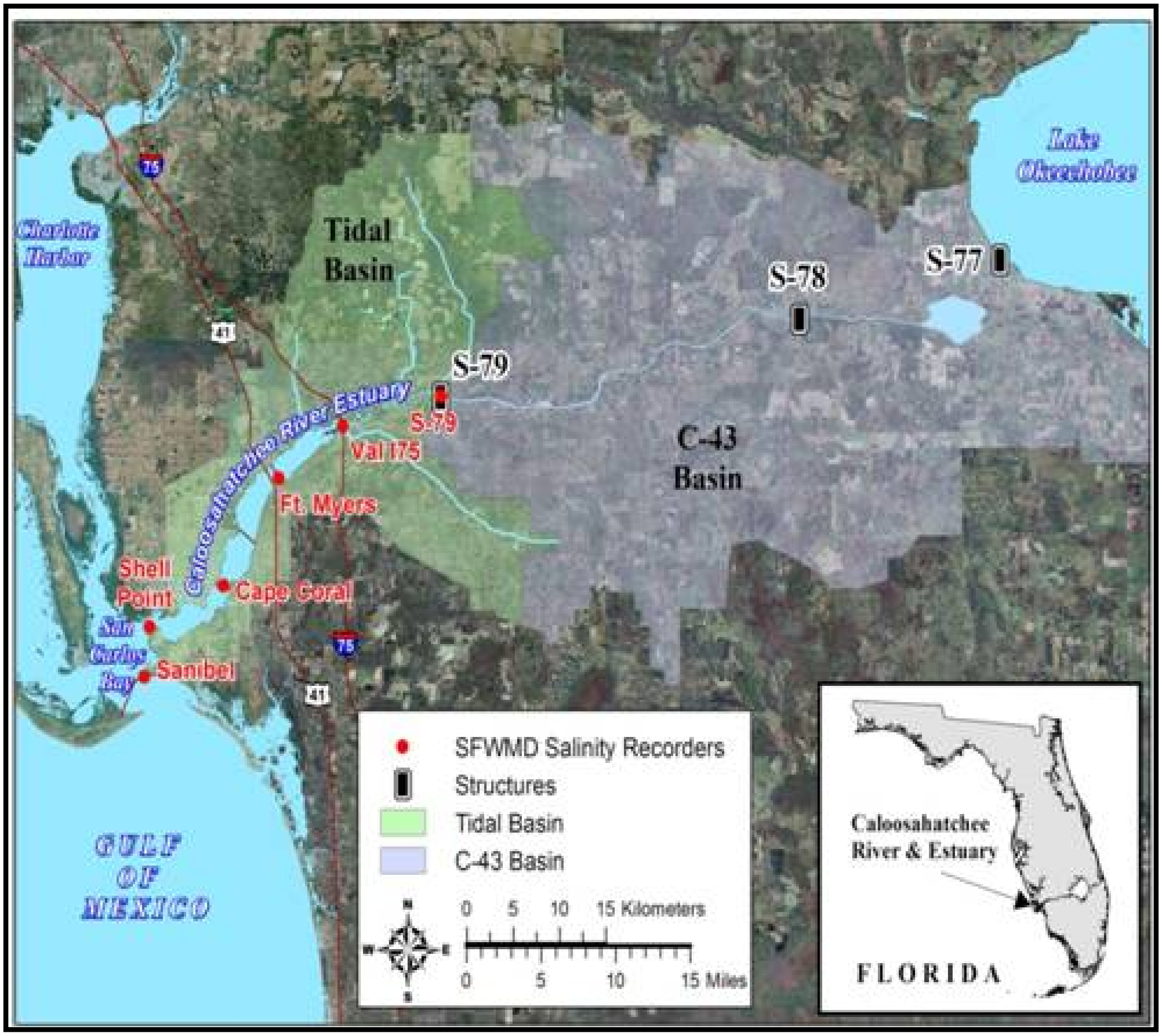


Figure 4-1. **Caloosahatchee River Estuary. (Note: SFWMD – South Florida Water Management District.)**

Inspection of the data reveals that differences between the ECB and the other two scenarios may be explained by a reduction in the frequency of low flow violation events. Because the C-43 West Basin Reservoir provides base flows to the CRE during the dry season, its inclusion in the FWO and ALTS conditions accounts for the observed reduction or system improvements. Despite lack of a statistical difference, it should be noted that when compared to the FWO, the ALTS condition has 13 fewer high flow months.

St. Lucie Estuary

RECOVER's review of the CEPP focused on total freshwater inflow. This includes flows at the S-80 structure, which integrates the discharge from Lake Okeechobee (S-308), and the C-44 basin as well as an estimate of inflows from other basins in the watershed. The general goal of the CERP is to maintain a salinity range favorable to fish, oysters and SAV, which necessarily requires addressing high volume, long duration discharge events from Lake Okeechobee, the C-23, and C-24 watersheds. A specific goal is to restore oyster populations in the area between the Roosevelt (US-1) and A1A bridges (**Figure 4-2**).

The CERP system-wide performance measure for Northern Estuaries salinity envelopes proposes a full restoration target of a mean monthly inflow into the SLE from all sources including groundwater and all surface water tributaries below 350 cfs for 31 months in a 36-year period, no more than 28 high flow events greater than 2,000 cfs based on a 14-day moving average and no regulatory discharge events of flows greater than 2,000 cfs from Lake Okeechobee based on a 14-day moving average (RECOVER 2007). For simplicity, we have evaluated frequencies of mean 15-day freshwater inflows by dividing each month in the 41-year period of record into two periods. Based on the salinity tolerances of oysters, flows less than about 350 cfs result in higher salinities at which oysters are susceptible to increased predation and disease. Flows in the 350–2,000 cfs range produce tolerable salinities. Flows greater than 2,000 cfs result in low, intolerable salinity within the estuary. Seagrasses in the Indian River Lagoon are damaged when flows exceed 3,000 cfs (**Table 4-3**). For analysis, the two highest flow classes were combined into one category (greater than 2,000 cfs).

Table 4-3. **Mean 15-day flow classes for the SLE and their expected ecological effects.**
(Total combined flows for S-80, C-44, C-23 and C-24.)

Mean Monthly Total Inflow	Ecological Response	Ranking Criteria
< 350 cfs	Salinity too high for optimal oyster health	Fewer is Better
350–2,000 cfs	Tolerable range	More is Better
2,000–3,000 cfs	Damage to estuary	Fewer is Better
> 3,000 cfs	Damage to SLE and Indian River Lagoon	Fewer is Better

Table 4-3 indicates the flow classes used to evaluate CERP effects on the SLE. The distribution of mean 15-day flows for the three scenarios is given in **Table 4-4**. Analysis of these flows yielded a statistically significant difference between scenarios (chi-square value X^2=29.7, df=4, p<0.001). Additional comparisons revealed that ALTS was significantly different from both ECB and FWO (X^2>18, df=2, p<0.001 in both cases). Inspection of the data suggests that these differences are due to a greater number of low flow periods (< 350 cfs), trending away from restoration, and a lower number of high flow periods (> 2,000 cfs), trending toward restoration. No statistical difference between ECB and FWO was detected (X^2=1.05, df=2, p=0.591).

Table 4-4. Distribution of 15-day flows over the 41-year simulated period of record.

Distribution of 15-day Combined Structure Flows			
CEPP Scenario:	**ECB**	**FWO**	**ALTS**
< 350 cfs	307	314	403
350–2,000 cfs	503	513	460
> 2,000 cfs	174	157	121

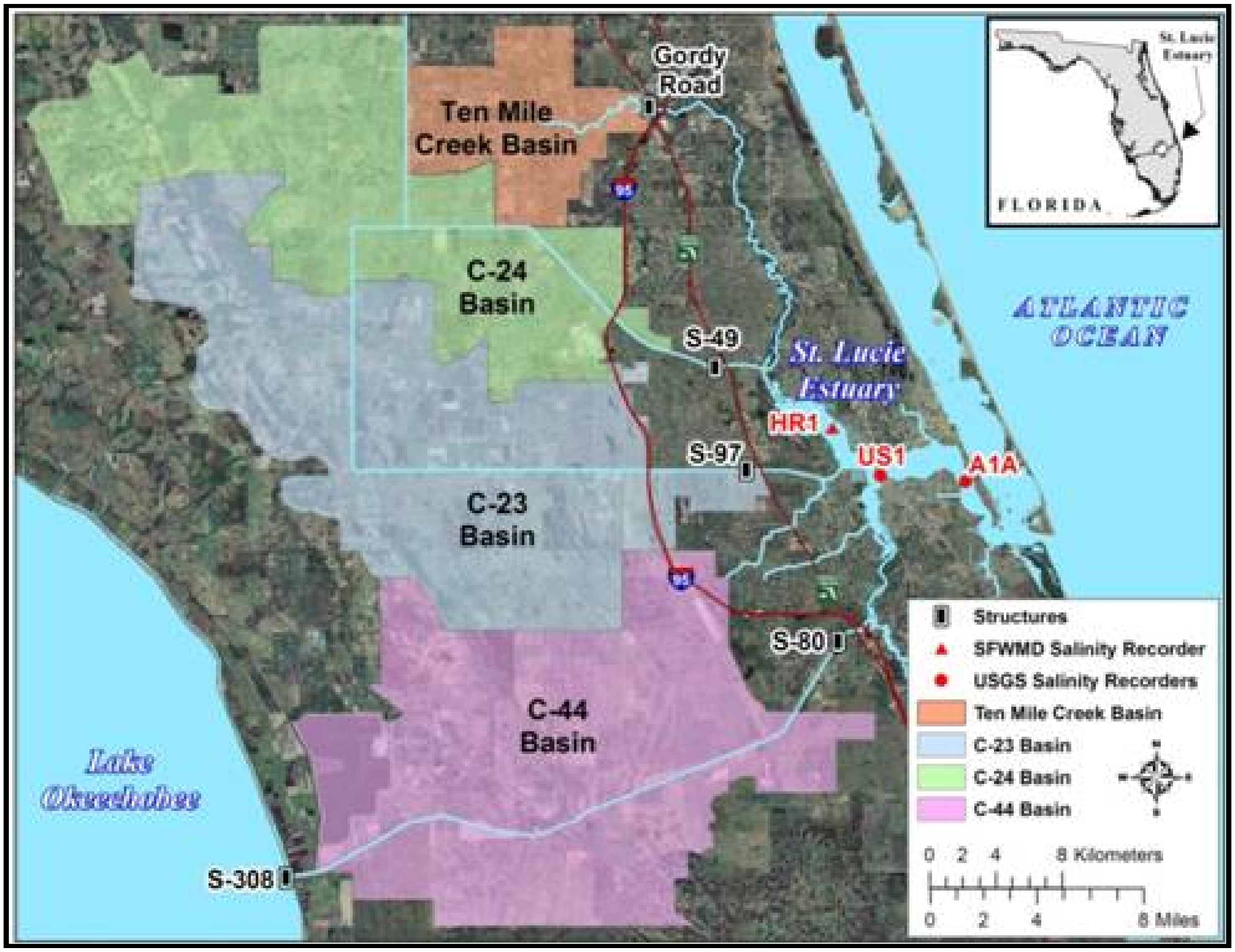


Figure 4-2. St. Lucie River Estuary.
(Note: SFWMD – South Florida Water Management District; USGS – United States Geological Survey.)

Salinity Performance Measures

The RSMBN model used to simulate the three scenarios evaluated here does not estimate salinity in either the SLE or CRE. Multivariate time series salinity models developed for the estuaries were applied for this analysis. The models consist of an autoregressive term representing the system persistence and an exogenous term accounting for driving factors including freshwater inflow, rainfall, and water surface elevation that cause salinity to vary as observed in the field (Wan 2012, Qiu and Wan in review). The models predict, and are calibrated against, daily salinities (r^2 = 0.89–0.95 between measured and simulated salinity data for model calibration). A total of 18 simulations were conducted to estimate daily average salinity during the 41-year period of record at given locations. The selected locations include I-75, Fort Myers, Cape Coral, Shell Point in the CRE, US-1 in the SLE, and Boy Scout Island in the Indian River Lagoon. The simulated salinity data were used for evaluation of salinity and ecological conditions.

Caloosahatchee Estuary

The CERP system-wide performance measure for Northern Estuaries salinity envelopes does not specify a salinity envelope at a particular location in the CRE (RECOVER 2007). Rather, the document refers to generalized beneficial salinity conditions and ranges. Tape grass, which is found in the upper estuary, requires low salinities less than 10 practical salinity units (psu). Seagrasses at the mouth of the CRE need high salinities greater than 20 psu. For the area around Shell Point and San Carlos Bay, a flow of 500–2,000 cfs results in salinities of 16–28 psu at all stations, conditions that are favorable to sustain and enhance CRE oyster populations. A time series of daily average salinity was evaluated at three locations in the CRE: Fort Myers, the Cape Coral Bridge and Shell Point. The three scenarios were compared by evaluating the number of days in particular salinity ranges. At Shell Point and Cape Coral, the salinity classes implied by the RECOVER salinity performance measure, 0–15.99 psu, 16–28 psu, and greater than 28 psu, were used (**Table 4-5**). The Cape Coral Bridge is thought to be near the upstream limit of persistent oyster populations. Scenarios with a greater number of days within the salinity envelope (16–28 psu) were considered more beneficial and less harmful to estuarine flora and fauna.

Table 4-5. Salinity envelopes used to evaluate the CEPP and their expected ecological effects.

Salinity Range (psu)	Ecological Response	Ranking Criteria
Fort Myers		
0 – 9.99	Tolerable for Tape grass	More is Better
10 – 14.99	Tape grass ceases to grow	Fewer is Better
≥15	Tape grass mortality	Fewer is Better
Shell Point		
0 – 16	Stress and mortality	Fewer is Better
16-28	Optimal range for Oysters	More is Better
>28	Increased oyster predation/disease	Fewer is Better

At Fort Myers, a salinity envelope based on the salinity tolerances of tape grass was employed to evaluate the three scenarios (**Table 4-6**). The 10-psu salinity value referenced in the RECOVER performance measure represents the generally accepted upper limit for a sustainable population (French and Moore 2003). Laboratory experiments summarized by Doering et al. (2002) indicated that growth of tape grass ceases at salinities between 10 and 15 psu. At salinities greater than 15 psu, mortality ensues.

Table 4-6. Distribution of daily average salinity at Fort Myers.

CEPP Scenario	Distribution of Daily Average Salinity		
	ECB	FWO	ALTS
0 - 9.99 psu	10,545	10,575	10,312
10 - 14.99 psu	2,192	4,038	4,249
$\geq$ 15 psu	2,238	362	414

At Fort Myers, statistical differences between the three scenarios were detected (**Table 4-6**; X^2=3010, df=4, p<0.001). Pairwise comparisons indicated that the ECB was significantly different from both the FWO and ALTS (X^2>1900, df=2, p<0.001 in both cases). Inspection of the data indicates that much of this difference is due to a greater number of days at salinities between 10 and 15 psu and fewer days at greater than or equal to 15 psu. The C-43 West Basin Reservoir CERP project is a feature of both the FWO and ALTS. Discharges from the reservoir during the dry season may account for the reduction of high salinity (greater than or equal to 15 psu) days. These results indicate that under the FWO and ALTS, areas upstream of Fort Myers would experience salinities more conducive to the growth of tape grass.

The distribution of salinity under the ALTS was also significantly different from the FWO (X^2=112.4, df=2, p<0.001). Inspection of the data indicate that much of this difference is due to a reduction in the number of days at salinities between 0 and 9.99 psu and increases in the number of days at higher salinities greater than 10 psu. While statistically significant, these relatively small differences are unlikely to have a significant ecological effect on the upper CRE.

At the Cape Coral Bridge and Shell Point (**Tables 4-7 and 4-8**), statistical differences between the three scenarios were also detected (X^2=812.2 for Cape Coral, X^2=333.5 for Shell Point, df=4, p<0.001). At both sites pairwise comparisons of the different scenarios revealed that all were statistically different from each other (X^2>37, df=1, p<0.001 in all cases). The ALTS had the greatest number of days within the 16–28 psu envelope, the FWO had an intermediate number, and the ECB had the least. By contrast, the order with respect to the number of days below 16 psu was ALTS < FWO < ECB. These patterns in salinity reflect the pattern in reduction of high flow months in the hydrologic performance measure.

Table 4-7. Distribution of daily average salinity at the Cape Coral Bridge.

CEPP Scenario	Distribution of Daily Average Salinity		
	ECB	FWO	ALTS
< 16 psu	8596	8461	8025
16–28 psu	5640	6404	6772
> 28 psu	733	110	178

Table 4-8. Distribution of daily average salinity at Shell Point.

CEPP Scenario	Distribution of Daily Average Salinity		
	ECB	FWO	ALTS
< 16 psu	2,490	2,104	1,728
16–28 psu	8,569	9,717	9,870
> 28 psu	3,916	3,155	3,377

St Lucie Estuary

The CERP system-wide performance measure Northern Estuaries salinity envelope target at the Roosevelt (US-1) Bridge (12–20 psu) was used in the analysis of daily average salinity for the SLE. The goal for the CERP is to reestablish a salinity range most favorable to marine fish, shellfish, oysters, and SAV. This is estimated to be 12–20 psu at the Roosevelt (US-1) Bridge. The number of days above, within, and below this envelope over the entire period of record provided a useful metric to compare the three scenarios (**Table 4-9**).

Table 4-9. Salinity envelope at the Roosevelt (US-1) Bridge used to evaluate the CEPP and the expected ecological effects.

Salinity Range	Ecological Response	Ranking Criteria
0–11.99 psu	Stress and mortality	Fewer is Better
12–20 psu	Optimal range for Oysters	More is Better
> 20 psu	Increased predation/disease	Fewer is Better

The distribution of salinity at the Roosevelt Bridge differed among the three alternatives (**Table 4-10**; X^2=486.4, df=4, p<0.001). Pairwise comparisons indicated that while the ECB and FWO had similar distributions (X^2=3.63, df=1, p=0.163), the ALTS differed from both the ECB and FWO (X^2>300.0, df=1, p<0.001 in both cases). The ALTS had fewer days at less than 12 psu and a higher number of days both within and above the 12–20 psu envelope. This pattern of generally higher salinity may reflect the fact that the ALTS had the fewest number of high discharge periods for the hydrologic performance measure and a higher number of low flow violations.

Table 4-10. Distribution of daily average salinity at the Roosevelt (US-1) Bridge.

CEPP Scenario	Distribution of Daily Average Salinity		
	ECB	FWO	ALTS
< 12 psu	7,638	7,463	6,032
12–20 psu	4,824	4,832	5,404
> 20psu	2,513	2,608	3,539

Ecological Performance

A series of ecological simulations were conducted to evaluate the relative differences among the three inflow scenarios—ECB, FWO, and ALTS—on oyster and seagrass densities in the CRE and SLE. Two separate base simulation models were used to assess the potential effects of salinities derived from the three inflow scenarios on oysters located at Cape Coral and Shell Point in the CRE (**Table 4-11**) (**Figure 4-1**). Additionally, a model of shoal grass was implemented to compare predicted salinities at Shell Point. For the SLE, the effects of predicted salinities among the three inflow scenarios were evaluated using oyster density at the Roosevelt US-1 Bridge and the density of manatee grass (*Syringodium filiforme*) at Boy Scout Island in the southern Indian River Lagoon located a few miles north of St. Lucie Inlet (**Table 4-12**)(**Figure 4-2**).

Table 4-11. **Summary of locations and simulation models for evaluation of Northern Estuaries potential responses to CEPP inflow scenarios.**

Estuary	Location	Model
CRE	Cape Coral	Oyster
	Shell Point	Oyster
	Shell Point	Shoal grass
SLE	Roosevelt (US-1) Bridge	Oyster
	Boy Scout Island	Manatee grass

The oyster simulation models for both estuaries were simplified versions of a framework derived to evaluate potential effects of increased area of oyster habitat on SLE water quality (Buzzelli et al. 2012a). This model uses an idealized oyster-salinity relationship, variable temperature, and a constant suspended solid concentration to predict oyster density. Similarly, the shoal and manatee grass simulations for both estuaries were simplified models derived to quantify effects of variable freshwater discharge and salinity on seagrass shoot density at Boy Scout Island (Buzzelli et al. 2012b). Water column chlorophyll *a* and turbidity were assumed constant although depth and the amount of colored dissolved organic matter (CDOM) and, therefore, submarine light varied dynamically throughout the 41-year simulations.

A total of 15 simulation models representing three salinity scenarios—ECB, FWO, and ALTS—and five location-biotic combinations (three oyster and two seagrass) were derived to evaluate CEPP Northern Everglades inflow alternatives. Each simulation covered 14,965 predictions of daily salinity at each location (41 year). Results were expressed as the predicted number of oysters or seagrass shoots in an acre of homogeneous habitat. The relative differences among the three salinity scenarios were visualized by comparing monthly averages with 41 individual values combined for each month of the calendar year. Additionally, the difference between the ECB and both the FWO and ALTS s were expressed as a percent difference over all 14,965 days.

Greatest oyster density (approximately 526,000 oysters per acre) was predicted in May at both the Cape Coral and Shell Point locations in the CRE. While more oysters were estimated under the ALTS relative to the FWO and ECB at Cape Coral, values were similar for the ALTS and FWO at the more downstream and saline Shell Point location (**Figures 4-3A** and **4-3B**). Compared to ECB, the ALTS scenario could account for a 7.1 percent increase in oyster density at Cape Coral compared to only 4.4 percent more at Shell Point (**Table 4-12**). The predicted seasonal pattern for oysters was similar at Roosevelt (US-1) Bridge in the SLE although densities were much lower than in the CRE (approximately 121,400 oysters per acre).

There were more oysters predicted under the ALTS relative to the FWO and ECB in the SLE (**Figure 4-3C**) with 14.4 percent more oysters (**Table 4-12**).

The maximum number of seagrass shoots occurred in August and September in both estuaries with approximately 202,300 shoots per acre of shoal grass at Shell Point in the CRE and approximately 242,800 shoots per acre of manatee grass at Boy Scout Island near the Saint Lucie Inlet (**Figures 4-3D** and **4**-**3E**). Overall shoot densities predicted under the ALTS were greater than for either the FWO or ECB. Compared to ECB, increases of 15.3 and 20.1 percent more seagrass shoots were predicted with salinities representative of the ALTS in the CRE and SLE, respectively (**Table 4-12**).

Table 4-12. **Results from estuarine ecological model scenarios related to the CEPP.**

Oysters per Acre	**ECB**	**FWO**	**ALTS**
Shell Point (CRE)	3,893,214	4,047,000 (+4.0%)	4,063,188 (+4.4%)
Cape Coral	2,671,020	2,715,537 (+1.7%)	2,861,229 (+7.1%)
US 1	574,674	594,909 (+3.5%)	655,614 (+14.4%)
Shoots per Acre	**ECB**	**FWO**	**ALTS**
Shell Point (shoal grass)	1,084,596	1,165,536 (+7.5%)	1,250,523 (+15.3%)
Boy Scout Island (manatee grass)	1,873,761	2,128,722 (+13.6%)	2,250,132 (+20.1%)

Note: Values are the total number of oysters (top half) or seagrass shoots (bottom half) in an acre of estuary habitat over all 14,975 days. Numbers in (parentheses) represent percent difference from the ECB.

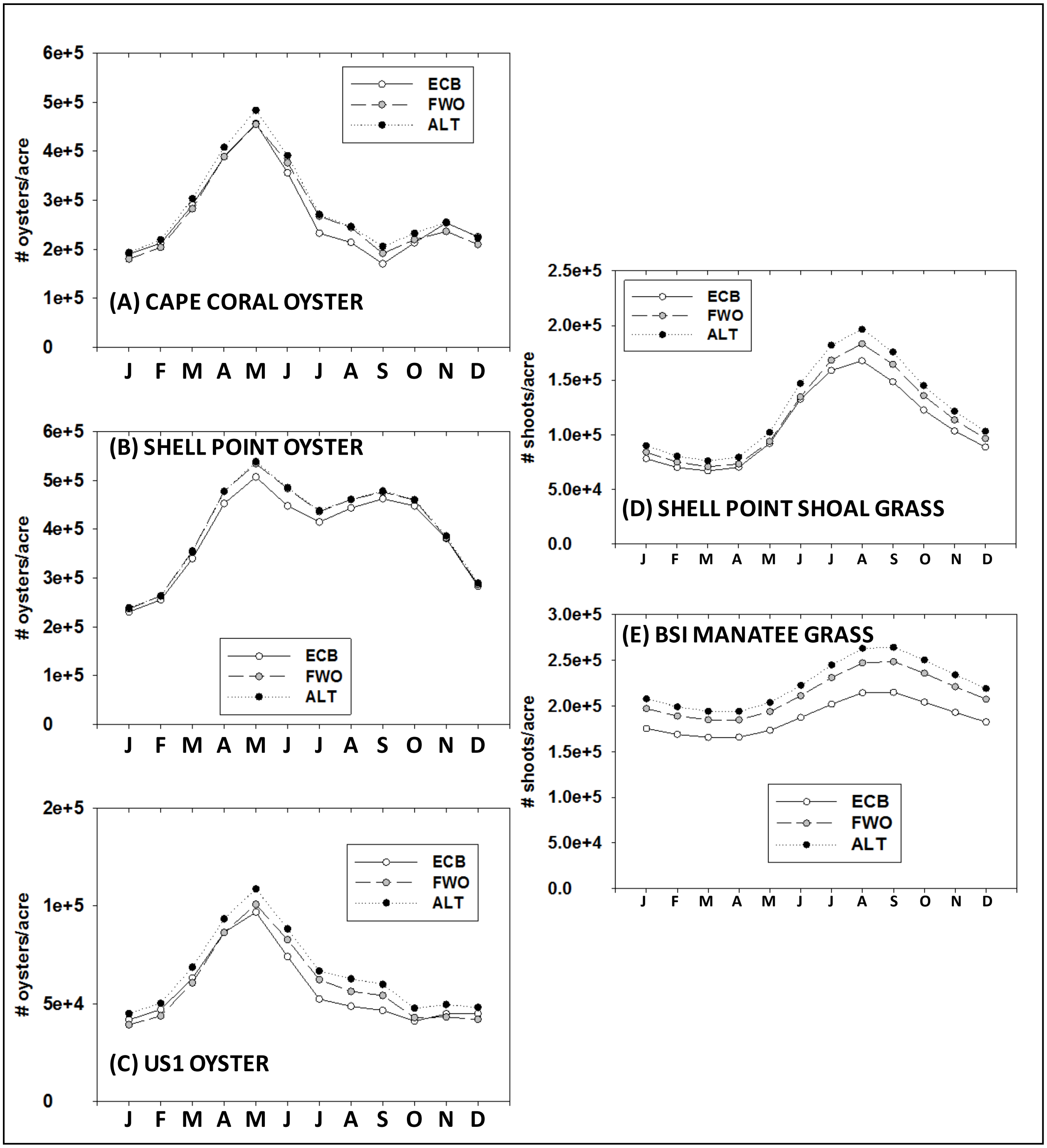


Figure 4-3. Predicted average monthly numbers of oysters (A-C) and seagrass shoots (D-E) per acre of habitat.

4.5 Summary

Modeling of the hydrology, salinity, and associated ecology of the SLE and CRE showed a small reduction in freshwater discharges from Lake Okeechobee to the estuaries. Although the difference was not statistically significant, the change is “in the right direction” for reducing peak flow events. Ecological projections for oysters and seagrasses, key species in the estuaries, indicated improvements with CEPP projected implementation. Modeling indicated less fresh water entering the SLE during low flow times, when small amounts of fresh water are needed. CEPP operations and future increments of the CEPP should remain aware of the need for small amounts of base flow into the estuaries during dryer times. Future operations of the Indian River Lagoon – South project can be optimized to help provide these base flows.

4.6 References

Buzzelli, C., M. Parker, S. Geiger, Y. Wan, P. Doering and D. Haunert. 2012a. Predicting system-scale impacts of oyster clearance on phytoplankton productivity in a small sub-tropical estuary. *Environmental Modeling & Assessment* DOI 10.1007/s10666-012-9338-y.

Buzzelli, C., B. Robbins, Z. Chen, D. Sun, Y. Wan, P. Doering, B. Welch and A. Schwarzchild. (2012b. Monitoring and modeling biomass dynamics of *Syringodium filiforme* (manatee grass) in southern Indian River Lagoon. *Estuaries & Coasts* 35:1401-1415.

Doering, P.H., R.H. Chamberlain and D. E. Haunert. 2002. Using submerged aquatic vegetation to establish minimum and maximum freshwater inflows to the Caloosahatchee Estuary, Florida. *Estuaries* 25(6B):1343-1354.

French, G.T. and K.A. Moore. 2003. Interactive effects of light and salinity on the growth, reproduction and photosynthetic capabilities of *Vallisneria americana* (Wild Celery). *Estuaries* 26:1255-1268.

Qiu, C. and Y. Wan. In review. Multivariate modeling of salinity time series in Caloosahatchee River Estuary. *Water Resources Researc*h.

RECOVER. 2007. Northern Estuaries Performance Measure – Salinity Envelopes CERP System-wide Performance Measure Documentation Sheet. Restoration Coordination and Verification Program c/o United States Army Corps of Engineers, Jacksonville, FL, and South Florida Water Management District, West Palm Beach, FL. April 5, 2007.

Wan, Y. 2012. Multivariate Modeling of Estuarine Salinity: A Case Study of St. Lucie Estuary. Technical Report for support of the Central Everglades Planning Project. South Florida Water Management District, West Palm Beach, FL.

5 GREATER EVERGLADES REGIONAL REPORT

RECOVER System-wide Regional Evaluation

Central Everglades Planning Project

GE Coordinators: Agnes McLean (Everglades National Park - ENP), Doug Donalson (USACE), Tom Dreschel (SFWMD),

Acknowledgements: Greater Everglades coordinators would like to thank the following individuals who contributed to the report - Andy LoSchiavo (USACE), Miles Meyer (USFWS), Fred Sklar (SFWMD), Stephanie Romanach, U.S. Geological Survey (USGS), Leonard Pearlstine (ENP), Joel Trexler, Florida International University (FIU) – contractor to USACE, Dale Gawlik, Florida Atlantic University (FAU) – contractor to USACE, and James Beerens, FAU – contractor to USACE. In addition, a special thanks goes to all of the agency staff and RECOVER principal investigators that participated in the GE evaluation meeting on January 18, 2013.

5.1 Introduction

An independent, ecological evaluation of the final array of Central Everglades Planning Project (CEPP) alternative plans was held January 18, 2013. The workshop was conducted by RECOVER Greater Everglades (GE) regional coordinators and included principal investigators (PIs) and staff. The purpose was to provide feedback to the CEPP project delivery team on the ecological performance both positive and negative of each of the final four CEPP alternative plans compared to the Future Without Project Condition (FWO) and to document the workshop findings.

Generally, RECOVER provides this independent scientific review by doing the following:

- Documenting the performance of the project alternatives using:
    - RECOVER approved system-wide performance measures,
    - Project hydrologic model output
    - Ecological planning tools, and
    - Best professional judgment
- Describing the ability of each alternative to meet the performance measure targets
- Describing the expected effects on the natural system

The predicted hydrologic performance of each of the RECOVER performance measures was used by the CEPP PDT to calculate habitat units, then were used in the cost-effectiveness / incremental cost analysis (See Appendix E and H). Therefore, the GE RECOVER evaluation workshop documented in **Section 5-3** focused on maps depicting hydrologic model output (e.g., flow vector maps, hydroperiod class maps, ponding depths, and stage), results of ecological planning tools and best professional judgment. Due to the nature of the hydrologic model output (RSMGL, Appendix A), most individuals analyzed four of the "years" out of the period of record (1965-2005), which have been characterized as being climatically wet (1995), dry (1989) and normal (1978). The fourth "year" was a composite of the results from the entire 41-year period of record.

5.2 Performance Measures for Greater Everglades

While not used comprehensively during the ecological workshop, performance measure results were available to workshop participants and so are listed here. The five RECOVER performance measures for the greater Everglades region used in the CEPP plan formulation and evaluation process are:

1. Inundation Duration in the Ridge and Slough Landscape – the percent period of record of inundation
2. Sheetflow in the Ridge and Slough Landscape – includes the timing, continuity and distribution of sheetflow
3. Hydrologic Surrogate for Soil Oxidation – a drought intensity index
4. Dry Events in Shark River Slough – measures the number and duration of dry events in Shark Slough
5. Slough Vegetation Suitability – measures hydroperiod, drydowns and both wet and dry season depths
6. Prey Base Fish Performance Measure – DeAngelis, Donalson, and Trexler (DDT) model measures prey-fish density using logistic growth equations based on days since last drydown.

Detailed documentation of results for performance measures 1-5 can be found in Appendix H of the CEPP Project Implementation Report (PIR). Performance measure 6 documentation and results are presented below.

Prey Base Fish Performance Measure Results

The DDT model uses days since last dry down (DSDD) to approximate densities of small (up to ~8cm) prey base fish. The equation used is fitted to data taken from 1996-2006 (RECOVER, 2011). The sampling points are shown in **Figure 5-1**. Equation 1 shows the basic equation with three parameters, r, K, and Y0. These parameters vary between different areas of the Greater Everglades. **Table 5-1** shows the parameter estimates for each of the three regions, WCA 3, Shark River Slough, and Taylor slough. **Figures 5-2, 5-3,** and **5-4** show the recovery curves for each of the regions. It is important to note the difference in return times for each region. In WCA 3, the time to full recovery is ~ three months, for Shark River Slough it is closer to 2.25 years, and even longer for Taylor Slough. It is hypothesized that the differences are related to relative isolation of the different areas and therefore the relative contribution of immigration/emigration vs. local growth to the recovery. This mechanism will be explicitly included in the next version of this model. It is important to remember the differences in these response curves because, for example, a 20% increase in fish density between two alternatives in WCA 3, is much easier to achieve than say a 10% increase in Shark River Slough. Full documentation of this Performance Measure can be found in Donalson et. al. 2010.

Equation 1:

$$\mathrm{LOG(TOTFISH+1)} = \frac{\mathrm{K}}{\left(1+\left(\left(\mathrm{K - Y0}\right)/\mathrm{Y0}\right)e^{\left(-r * DSLDD\right)}\right)}$$

DSLDD = days since last dry down
r = growth constant
TOTFISH = total small-sized fish density (number of individuals) per m^2
K=asymptotic density
Y0=Y intercept

Table 5-1. Trexler small-sized fish density logistic regression equation parameters per monitoring region

Monitoring region	WCA-3A/B	Shark Slough	Taylor Slough
K	2.901	2.757	2.625
r	0.097	0.006	0.003
Y0	0.300	1.486	1.08

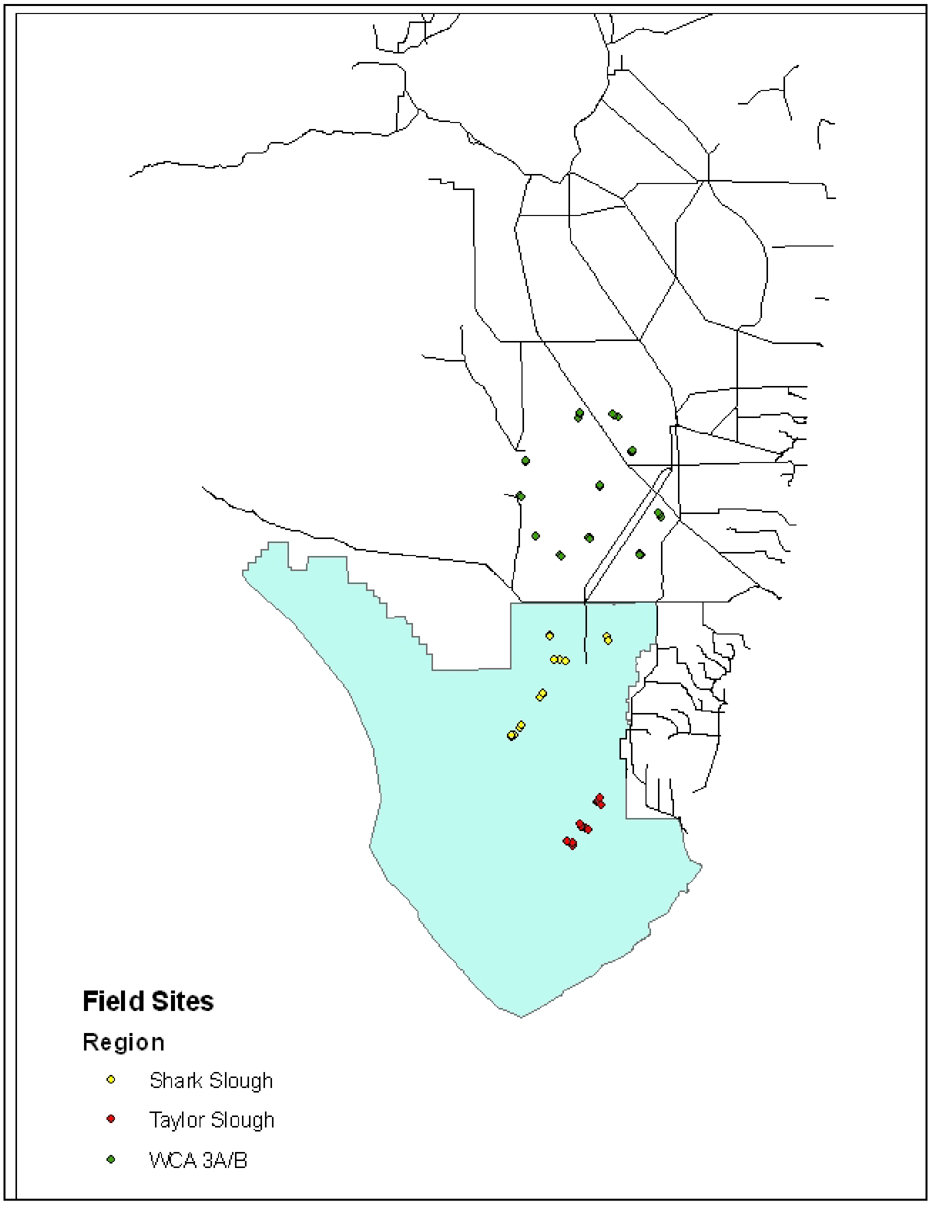


Figure 5-1. **Trexler's sampling sites within the Greater Everglades region. Canals and highlighted Everglades Nation Park boundary are included for reference purposes.**

Figures 5-2, 5-3, and **5-4** show the best logistic model fits for predicting small-sized fish density/m^2 recovery of fish density since the last dry down event based on Equation 1.

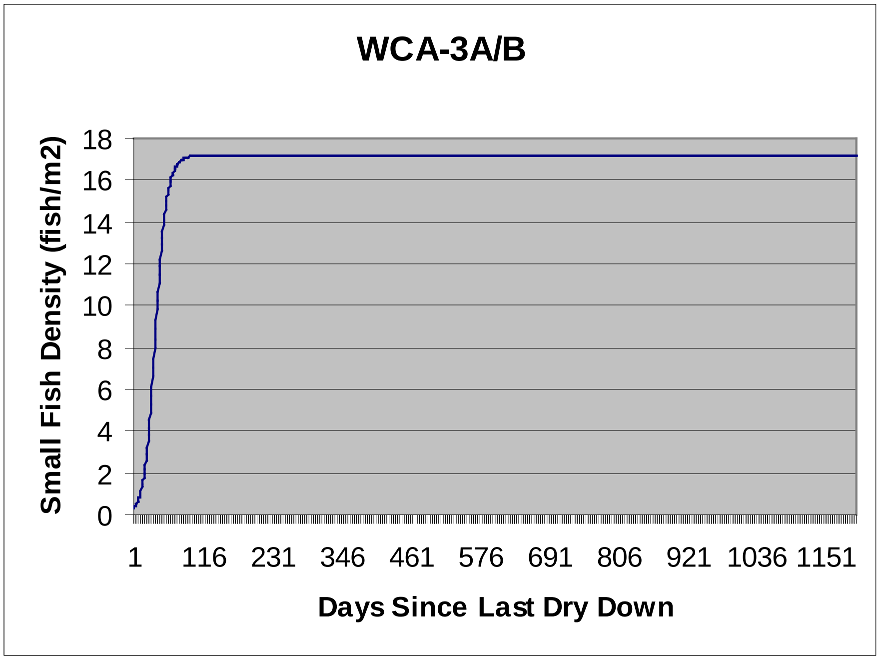


Figure 5-2. Model fit for total small-sized fish density since last dry down event collected in WCA 3A/3B based on the Trexler (1996-2006) data

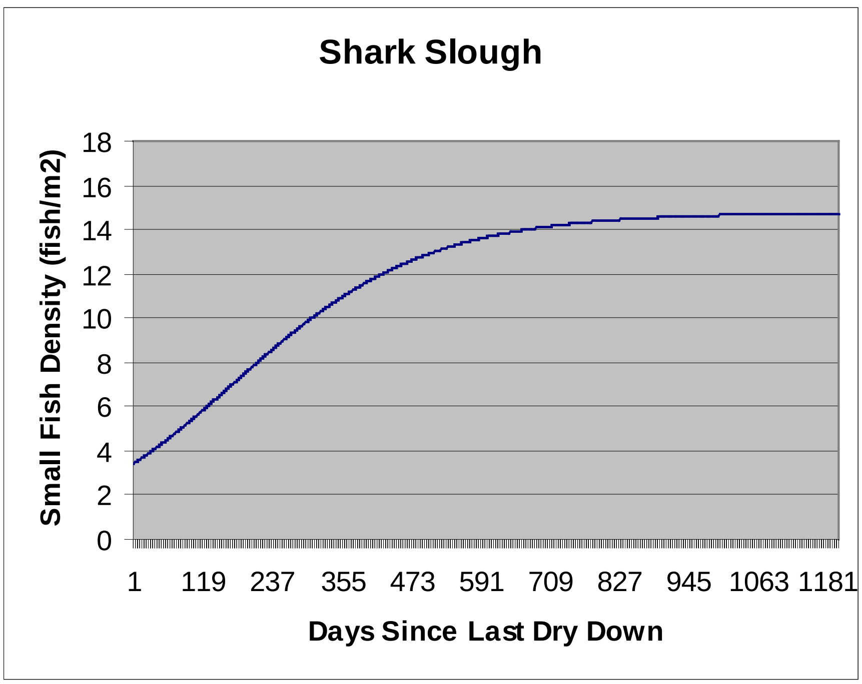


Figure 5-3. Model fit for total small-sized fish density since last dry down event collected in Shark Slough based on the Trexler (1996-2006) data

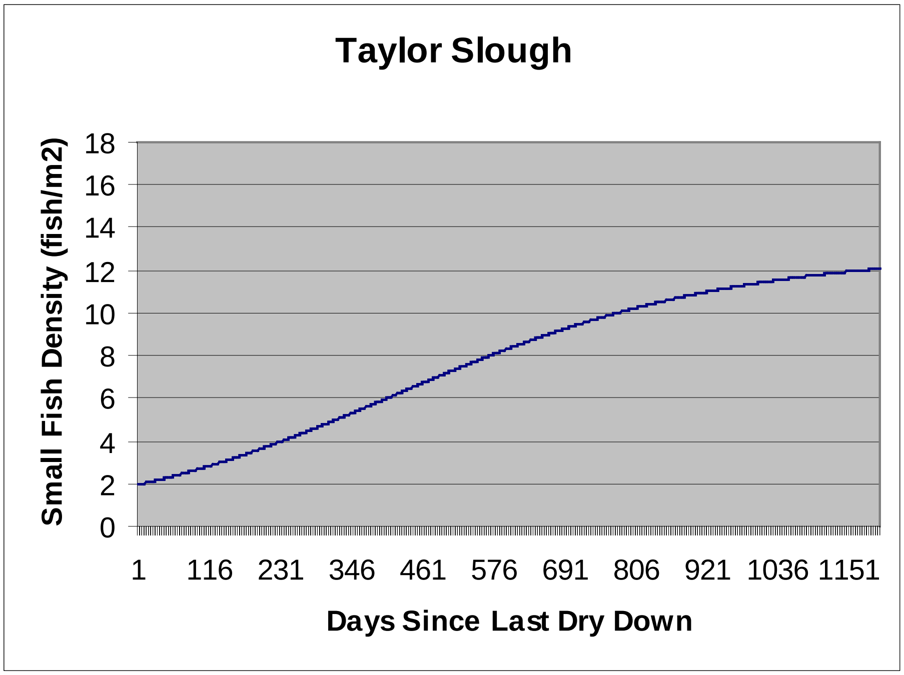


Figure 5-4. Model fit for total small-sized fish density since last dry down event collected in Taylor Slough based on the Trexler (1996-2006) data.

WCA 3

In WCA 3A, the three northern most sites show the greatest lift with respect to FWO (see **Figure 5-5**). The greatest increase is seen in site 10 which is to the east of Miami Canal. The increase of ~30% occurs in all four alternatives. In site 9, west of the Miami Canal the lift is closer to 17%, which although less, is still a significant increase from FWO. Site 11 shows a 7%-10% increase. Given that it is south of sites 9 and 10, and the fact that all the other sites, including site 6 which is at about the same latitude, have very little change with respect to FWO; it is not unreasonable to suppose that north of site 11 would see even a greater lift. Catano and Trexler, 2013, *Figures 6-9* indicate that this supposition is reasonable. The southern sites, 1-6, show little change between the alternatives and FWO and sites 1 and 2 show even some very small loss indicating drying. For WCA 3A, the two best performing alternatives would probably be Alts 1 and 4, but all four alternatives improve prey density over FWO. WCA 3B (sites 7 and 8) show some improvement, with Alts 2 and 3 having a lift of slightly over 10%. Here the most lift comes from Alts 2 and 3. Again however, the differences between the alternatives overall is such that any of the four could be chosen.

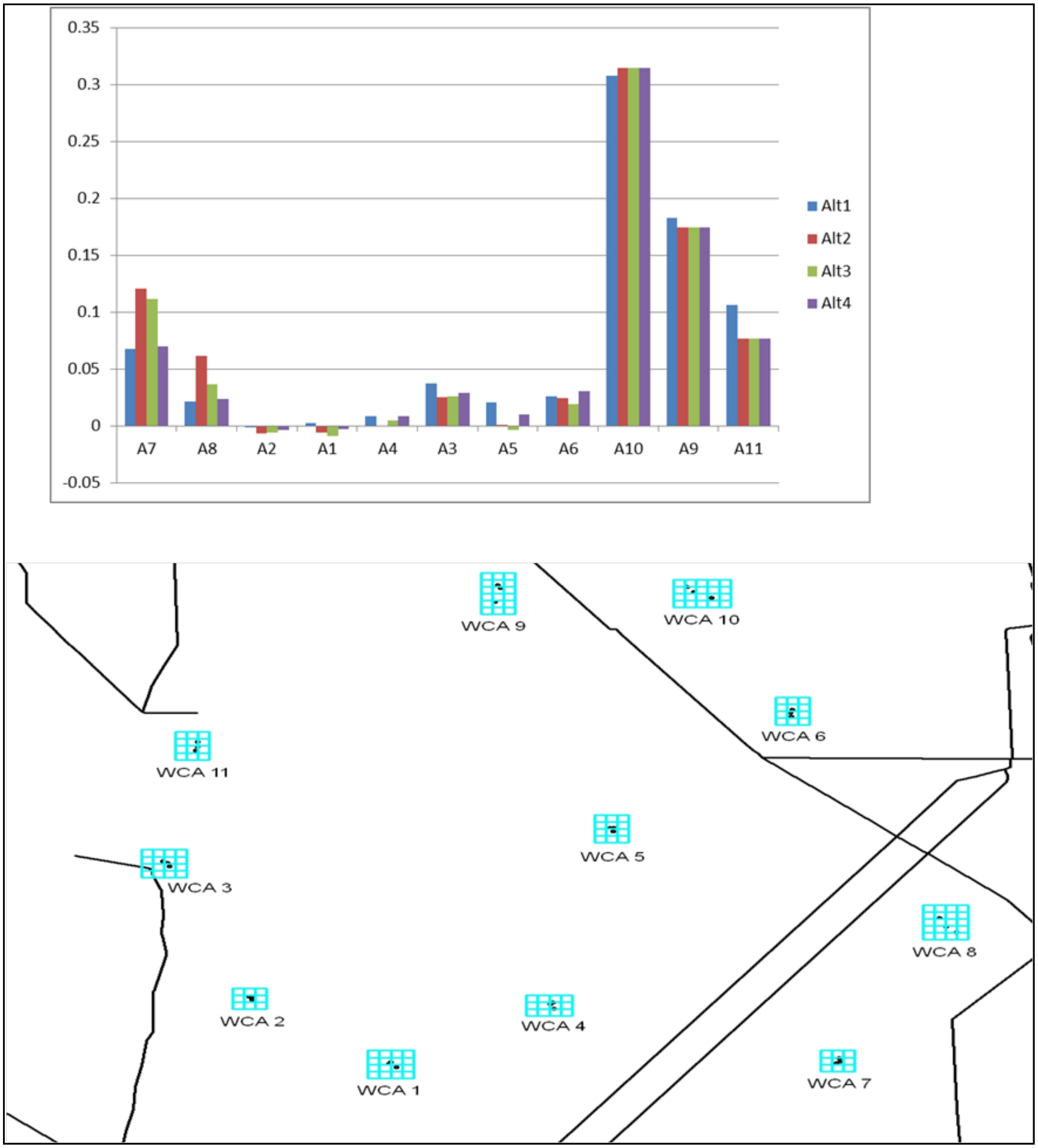


Figure 5-5. **Prey-base Fish Results for WCA 3 with sampling sites. Units of results are differences scaled 0-1. Canals are included in the map for reference purposes.**

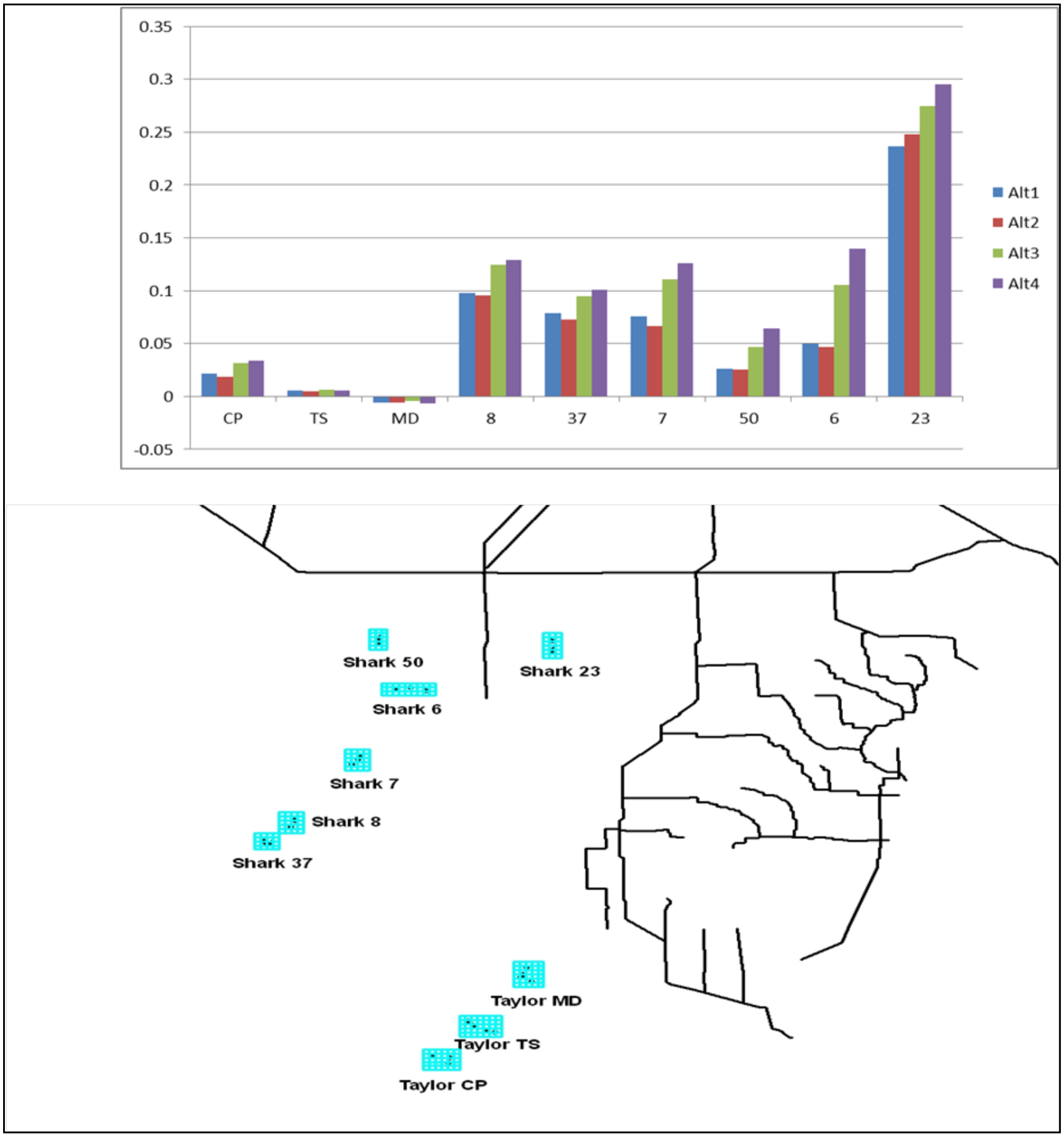


Figure 5-6. **Prey-Base Fish Results for Shark River Slough and Taylor Slough with sampling sites. Units of results are differences scaled 0-1. Canals are included in the map for reference purposes.**

Shark River Slough

The Shark River Slough (SRS) results (**Figure 5-6**) show both interesting and encouraging dynamics. The two sites directly below the Tamiami trail, site 23 on the west side of the L-67 extension, and site 23 on the east, show very different dynamics, as the greater part of the water entering SRS is entering from the east. Site 23 shoes a lift of ~24%-29%. As was mentioned in the introduction, because of the much longer recovery curve between WCA 3 and SRS (**Figures 5-2 and 5-3**), this is a much more significant change than was seen in, for example WCA 3A site 10. It is interesting to note that site 6 actually has more lift than site 50, even though it is on the same side of the L-67 extension as site 50 and south of it. This would indicate the possibility that the water coming in from the east has enough volume to actually "backflow" up the west side of the L-67 extension. There is little to distinguish between Sites 7, 8, and 37. This in itself is interesting when comparing to WCA 3A, as the benefits don't decrease as the water moves south. This is also support for the Southern Costal Systems benefits in Florida Bay. Overall, Alt 4 provides the greatest benefits for SRS, but all alternatives would provide excellent benefits over FWO.

Taylor Slough

There are only three sites in Taylor Slough, from north to south, MD, TS, and CP. There are no significant changes with respect to FWO for MD and TS. However, the southernmost site, CP, does show some change that is important given the very long recovery curve from dry down (**Figure 5-4**). One hypothesis, as with SRS site 6, the water is coming as a back flow up Taylor Slough from the increased flow through SRS. There is not discernment between the best alternative based on benefits for Taylor Slough.

5.3 Other Information Sources and Evaluation Process

The evaluation process involved three steps:

1. Individual Evaluations – a "wall walk" was undertaken by workshop participants to review hydrologic model output and results of ecological planning tools, which were posted on the walls of the meeting room. Each participant was given a worksheet upon which to annotate their thoughts on the ecological performance of the alternative plans.
2. Group Evaluations – workshop participants then broke into small groups to discuss their views of the alternative plans.
3. Workshop discussion – all participants came back together to hear report outs from the small groups and to collectively discuss the findings.

Consolidated conclusions from the workshop are listed below:

All CEPP alternatives are a significant improvement towards restoring the Everglades system compared to the FWO project condition. Hydrologic output indicated there would be better hydroperiods and more sheetflow in Water Conservation Area (WCA) 3A, WCA 3B, and Everglades National Park with all alternatives. **Figure 5-7** displays hydroperiod maps during a dry year (1989) for the four project alternatives compared to the FWO. Hydroperiods are much longer in Northern WCA 3, WCA 3B, and ENP for the four alternatives (blue circle), while the FWO is slightly longer in WCA 2 (red circle).

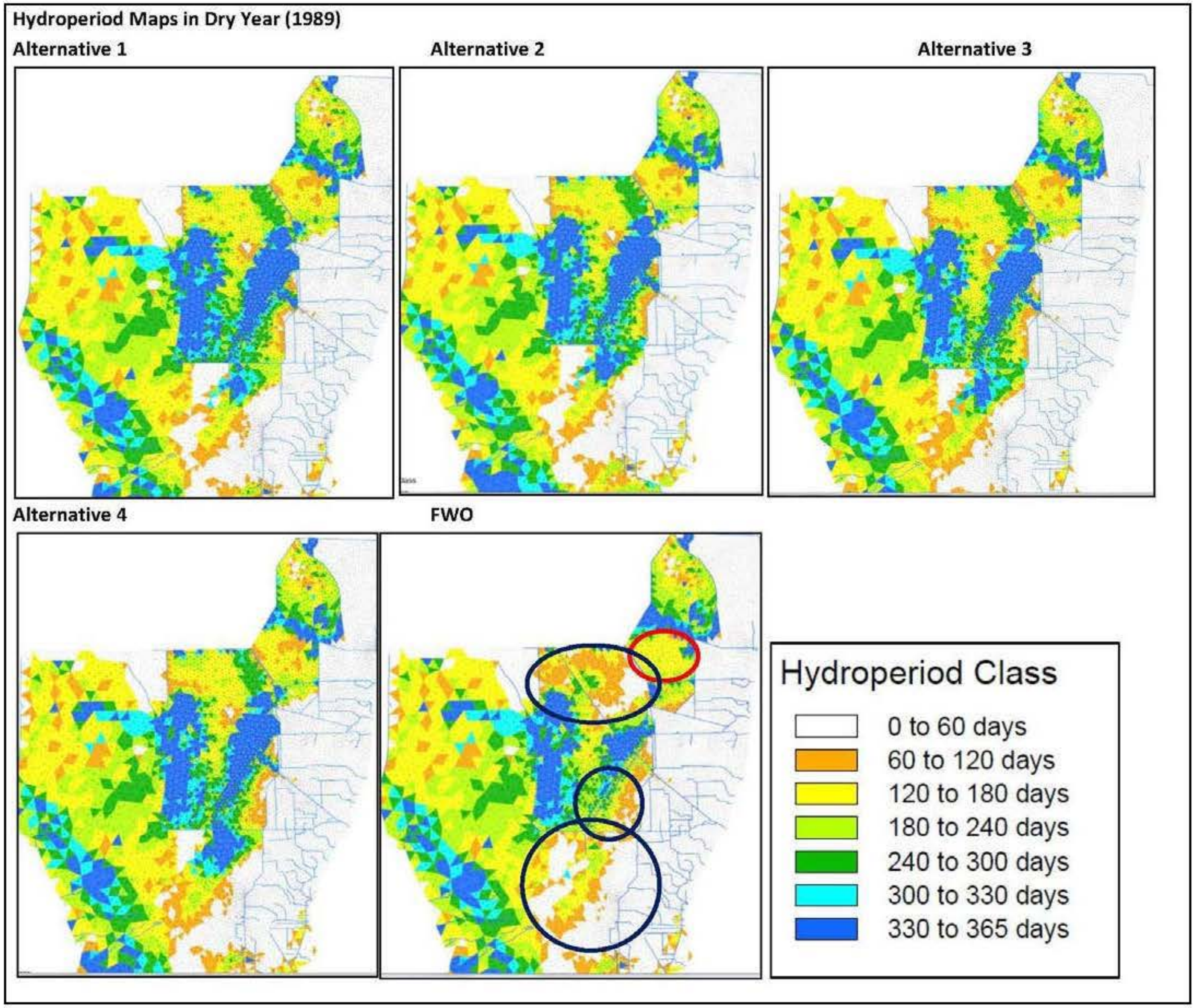


Figure 5-7. Hydroperiod during a dry year (1989) for the four project alternatives compared to the FWO

Figure 5-8 displays average annual surface water flow vectors from the 41 yr period of record for each alternative compared to the FWO. The darker the color (dark blue) the stronger the flow (volume and likely velocity) of surface water. Project alternatives show more sheet flow in northern and central WCA 3A and from WCA 3B to ENP, and slightly more flow to the southwest coast (dark blue circles). FWO has more flow through WCA 2 (dark red circle).

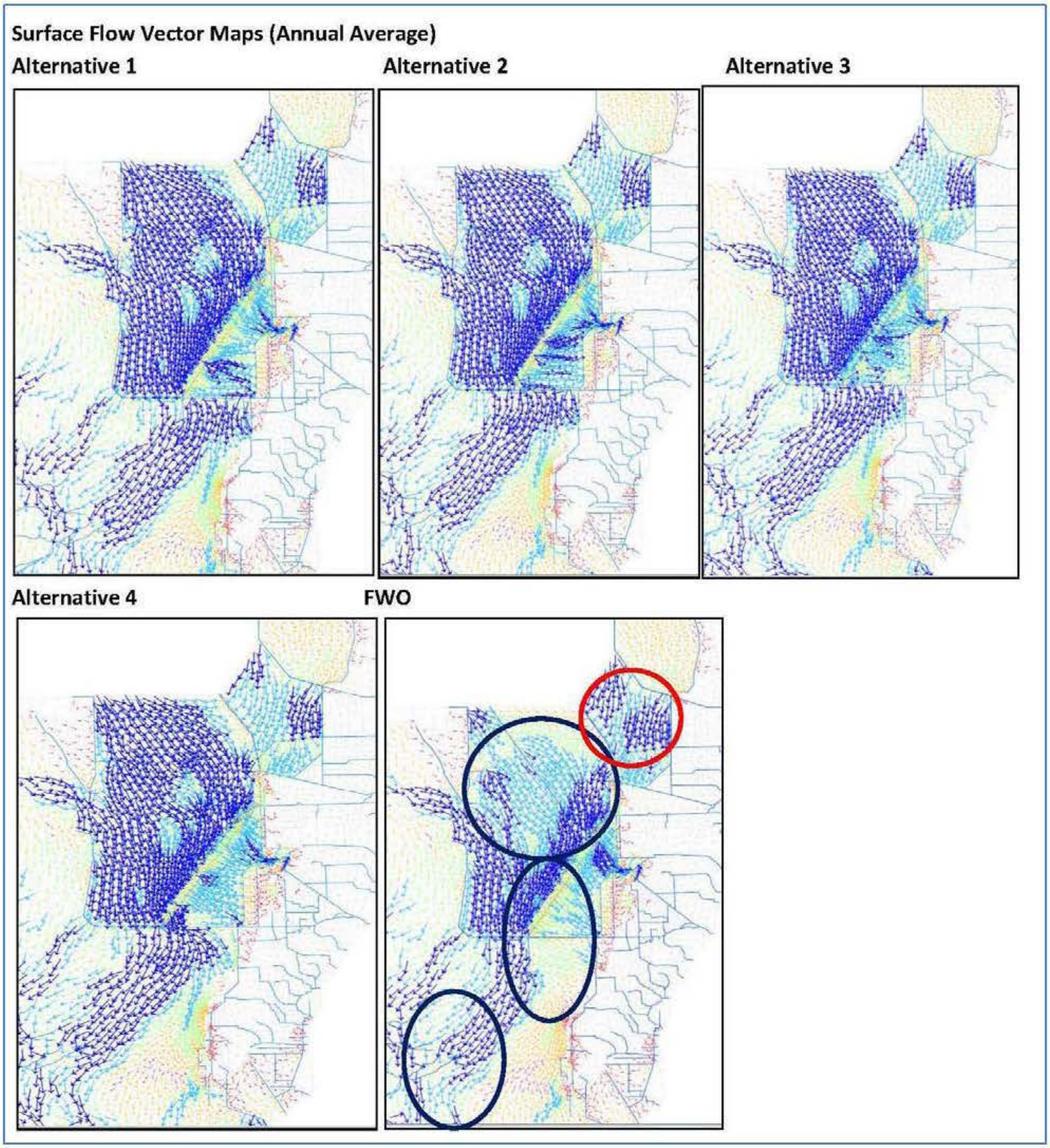


Figure 5-8. **Average Annual Surface Water Flow Vector Maps for each alternative compared to FWO.**

Transect Flow Location Diagram and Flow Amount Charts

The RSM model provides model output data over a given transect line. **Figure 5-9** below displays the placement of each transect line in the RSM grid and the associated transect number. Transect 5 (T5) (**Figure 5-10**), 6 (T6) (**Figure 5-11**), and 18(T18) (**Figure 5-12**), display average flows in thousand acre-feet per year and indicate significant more flow with each alternative compared to the FWO (left). Alternative 1 (second column from left) provides more flow to T5, while alternatives 2-4 provide slightly more water to T6.

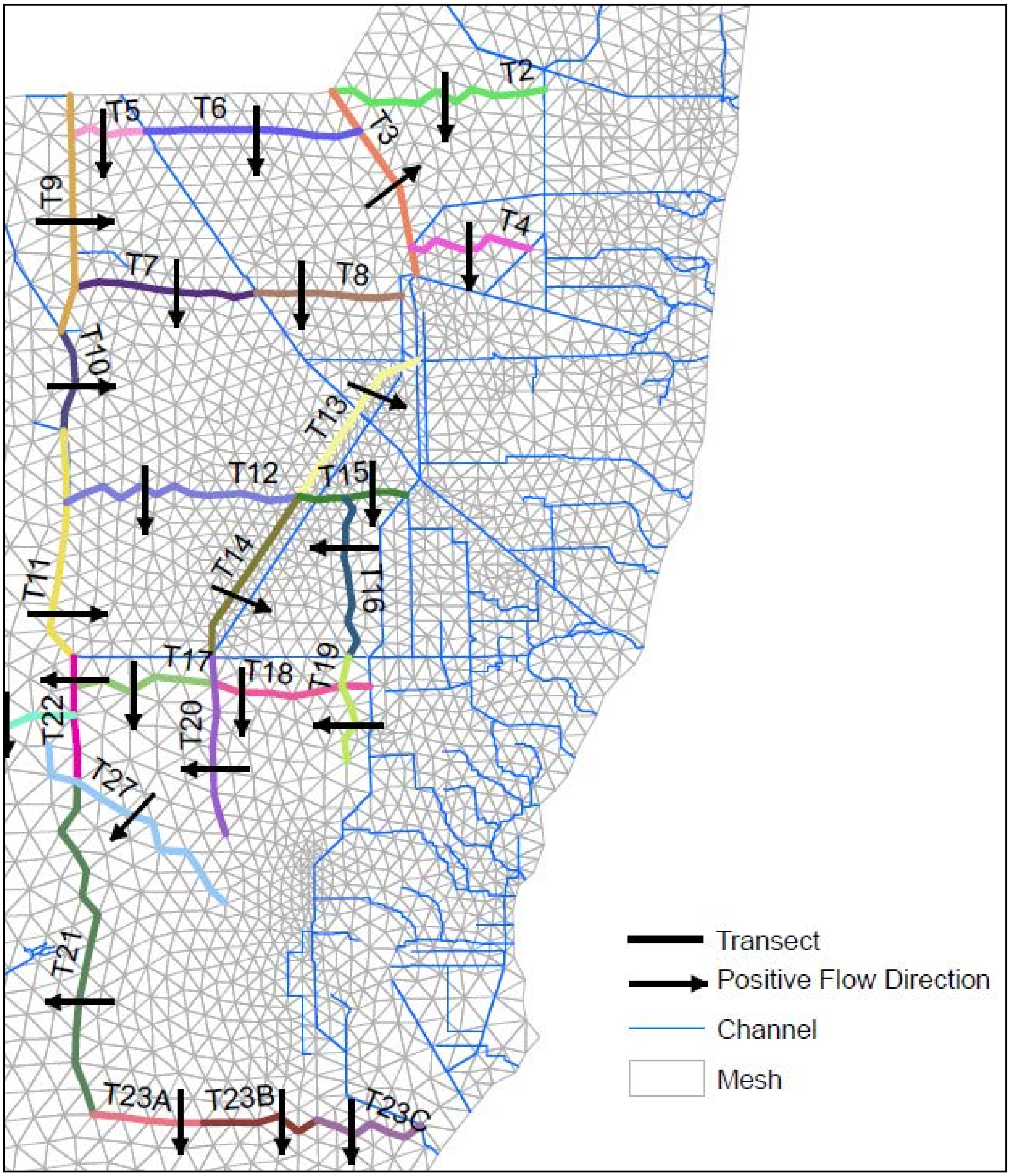


Figure 5-9. **Transect number and location to interpret flows from the RSM model data.**

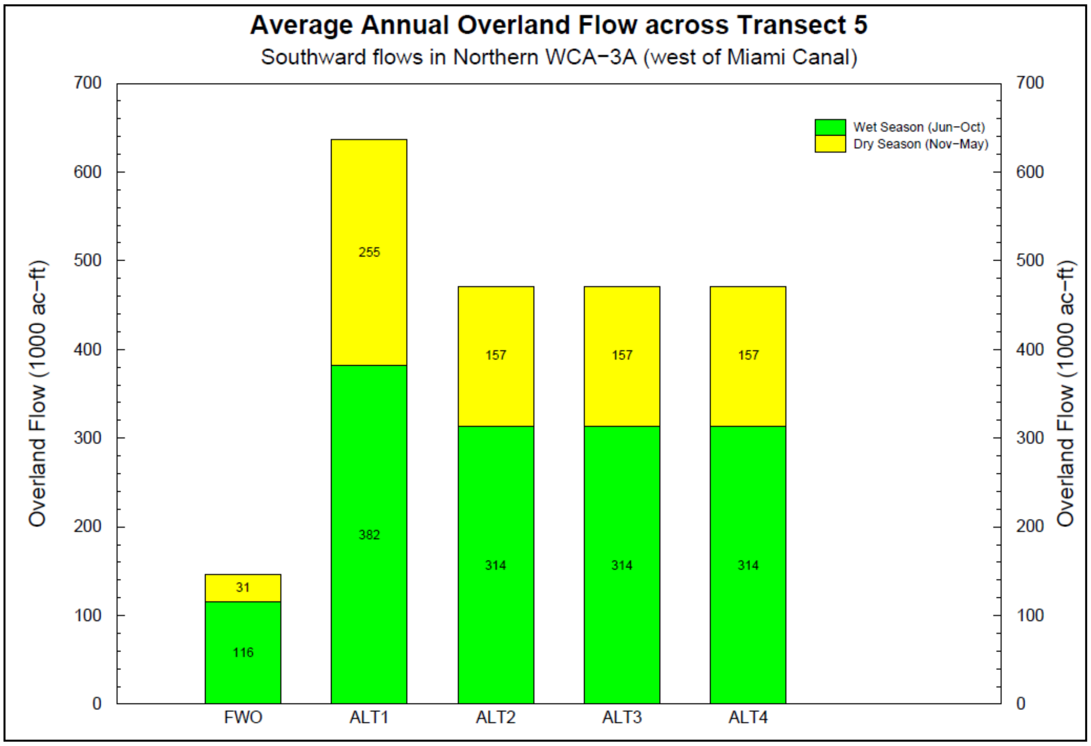


Figure 5-10. **Transect 5 (T5) average annual overland flow.**

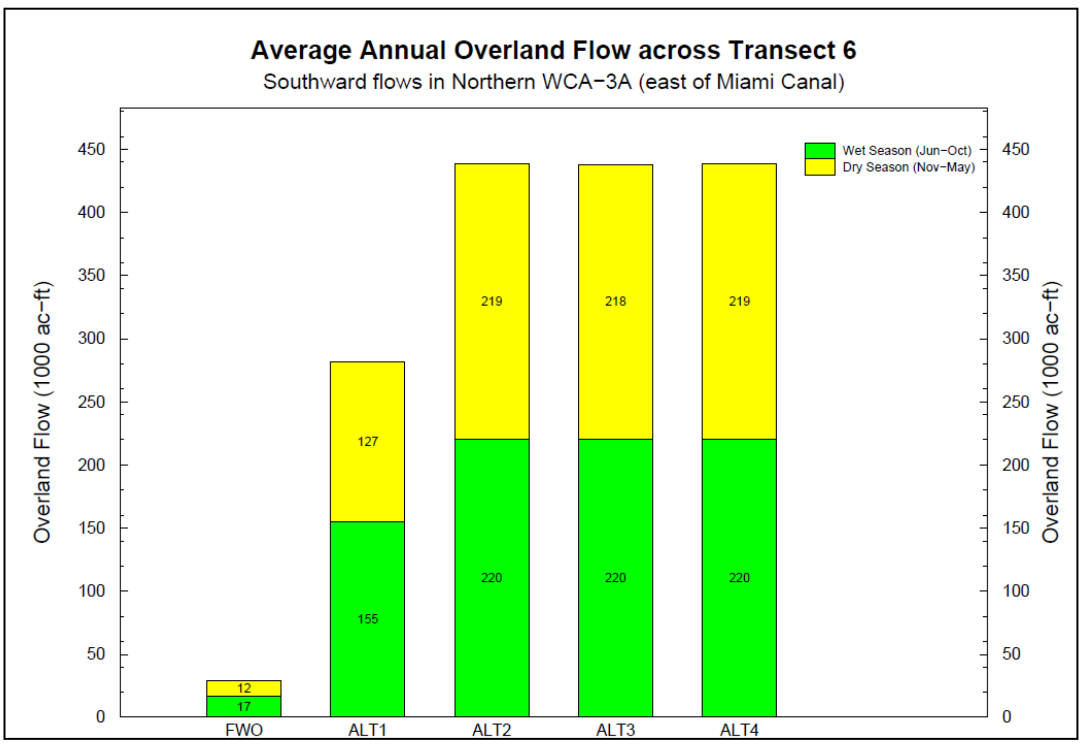


Figure 5-11. **Transect 6 (T6) average annual overland flow.**

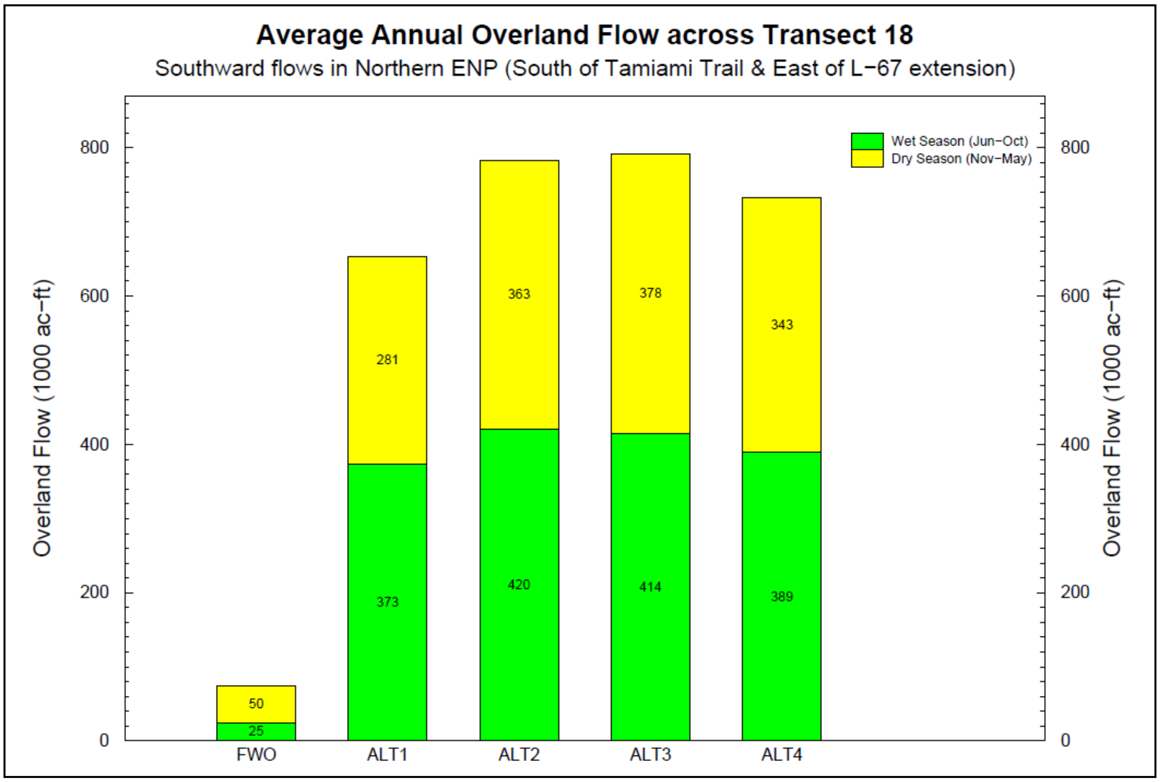


Figure 5-12. Transect 18 (T18) average annual overland flow.

Northern WCA 3A and Shark River Slough would experience less soil oxidation, promoting peat accretion necessary to rebuild the complex mosaic of habitats across the landscape. While alternative 1 supplies more water to northwest WCA 3A, alternatives 2, 3, 4 provide more water to northwest WCA 3A as well as more water to northeastern WCA 3A, promoting sheetflow to a greater area.

All alternatives showed improved ecological performance for fish, wading birds, and apple snails in the northern and some central areas of WCA 3A, as well as in Shark River Slough, as described in the ecological planning tool summaries below. Alternatives 3 and 4 provide more water to Shark River Slough and the southern Marl Prairies compared to alternatives 1 and 2. It is thought this would improve conditions for fish, wading birds, alligators, tree islands and ridge and slough habitat. Alternative 4 appears to make the most efficient use of the roughly additional 200,000 acre-feet of water added to the system by funneling the "new" water as well as improving the distribution of the existing water through the Blue Shanty flow way. The Blue Shanty levee in alternative 4 could be moved to the east to avoid impacting large tree islands in WCA 3B and better align with the Tamiami Trail Bridge. This could allow for adaptive management opportunities for rehydrating these over-drained tree islands, as inflows into WCA 3B are controllable. While alternative 4 doesn't meet slough vegetation performance in WCA 3B as well as alternative 3, overall it may pose less risk to tree islands east of the levee and lessen the need for seepage management features. Alternative 4 appears to result in widening Shark River Slough and improving wading bird habitat on the flanks of the Eastern Marl Prairies. It also provides more flow to the southern coastal systems (i.e., Florida Bay) during wet years.

Generally, passive structures are favored; concerns were expressed regarding the use of pumps in alternative 3 that would allow the "pull" of water out of the southern end of WCA 3B. While it was acknowledged that alternative 4 removed parts of the L-67C, L-67 extension and L-29 levees, concerns were also expressed regarding adding additional compartmentalization in WCA 3B (i.e., the Blue Shanty levee).

Areas that would need adaptive management of operations to increase the likelihood of achieving more restoration benefits, while avoiding impact to sensitive resources, are:

- Southern WCA 3A along L-29 and L-67A,
- WCA 3B, and
- Marl prairies in Everglades National Park

It is important to focus operations to manage for flow and stage variance, as opposed to focusing on average hydrologic regimes. In other words, every so often the system does need to dry down to promote healthy ridge and slough/tree island formation, and should not always be kept wet in the areas of the system that are more likely to be wetter (southern WCA 3A along L-29 and L-67s). CEPP components chosen for the tentatively selected plan should not preclude the ability to add additional features to the project in the future, as more clean water becomes available.

Ecological planning tools

Documentation of the ecological planning tools presented by individual modelers and principal investigators can be reviewed in Appendix H. Brief summaries of the information provided by these tools are provided below:

<u>ELVeS</u>
The Everglades Landscape Vegetation Succession model (ELVeS) is a spatially explicit simulation of vegetation community dynamics over time in response to changes in environmental conditions (Pearlstine, et al., 2011). In examining the dominant vegetation communities selected by ELVeS at the end of the 41-year hydrologic period of record, little difference is discernible among the alternatives and FWO or Existing Condition Baseline (ECB). Open water is eliminated in all of the alternatives in southern WCA 2B and increased wetting in alternative 1 is being expressed along the western edge of northern WCA 3A with pockets of spikerush (*Eleocharis* spp.). Northern WCA 3A in the ECB and FWO is drier than it is expected to be in the alternatives and is characterized by willow and shrubs. In the alternatives, water deliveries to northern WCA 3A result in ELVeS probabilities for sawgrass becoming quite high and following the pathways of water flow. Increased wetting of northern WCA 3B can also be observed in alternative 2 and a further increase in sawgrass probabilities within the alternative 4 flow way. These changes are also apparent in the open marsh (deeper water, sparser emergent marsh vegetation) community probabilities for these alternatives.

<u>Marl Prairie Indicator</u>
The Marl Prairie Indicator model looks at discontinuous hydroperiods between May and April, Cape Sable Seaside Sparrow (CSSS) Nesting Season water depth (March 1-July 15), and Average Wet and Dry season water depths to calculate whether the habitat is suitable for CSSS (Pearlstine, et al., 2013). Overall, there appears to be little impact of the alternatives on lift of marl prairie habitat for Cape Sable seaside sparrow subpopulations A, B, C, or D. The alternatives - and alternative 2 in particular- increase habitat suitability for a series of model cells just northwest of the subpopulation A boundary. The lowered suitability scores in subpopulation E are occurring mostly in the northern area of the

subpopulation; however, there are no areas of notable gains. Subpopulation F scores mostly decline along its western boundary with lesser, but still substantial gains to the east that are masked by averaging with the losses on the western boundary.

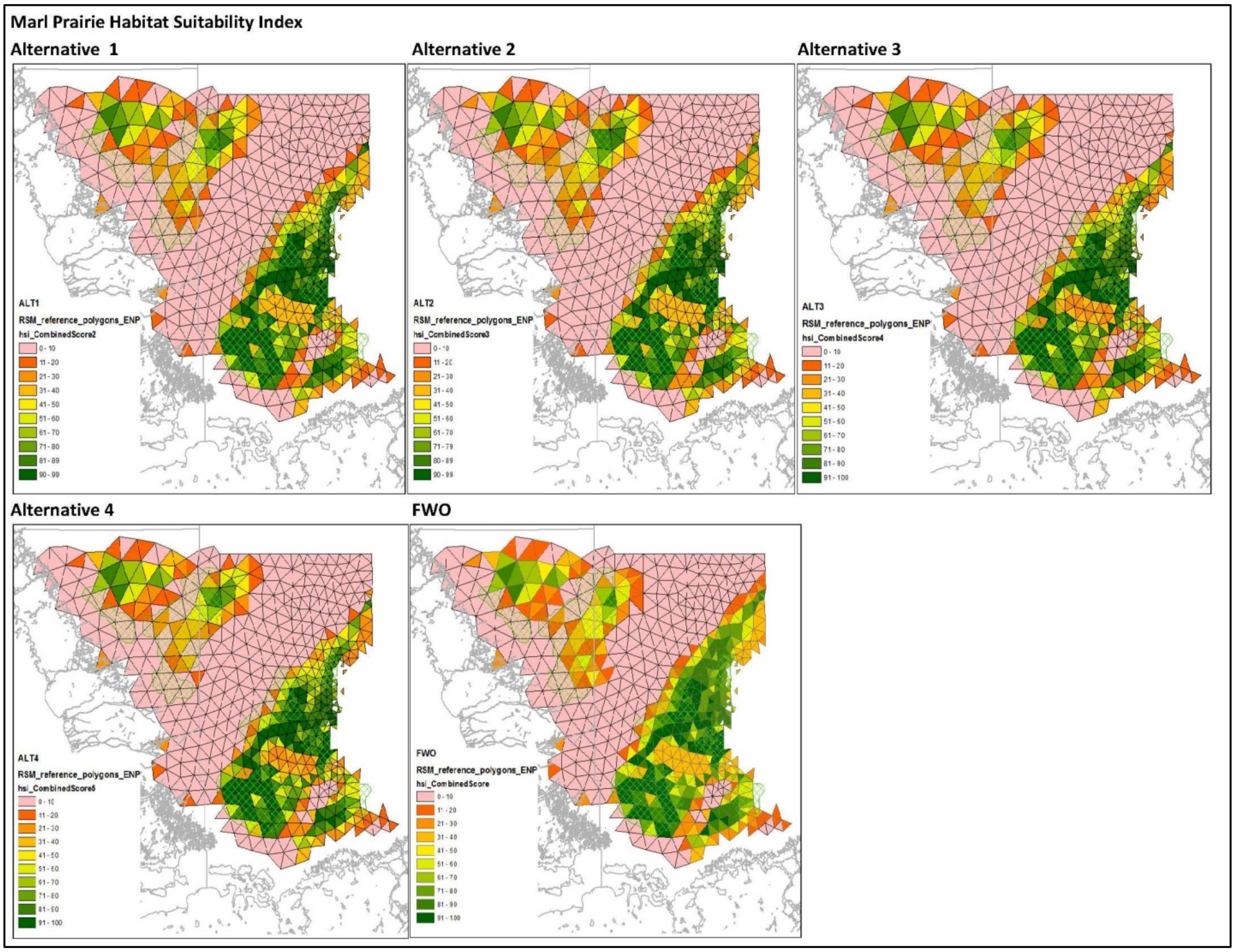


Figure 5-13. **Displays Marl Prairie Habitat Suitability Index Maps for all alternatives and the FWO. Shading from pink to green represents less to more suitable marl prairie habitat.**

<u>American Alligator Production Probability Index</u>

The Alligator Production Probability Index model incorporates concepts from existing alligator habitat suitability models and the literature to estimate alligator production probability for breeding and nesting success (Shinde, et al., Draft). **Table 5-2** and **Figure 5-14** display cumulative alligator habitat suitability index score lift for each alternative and the existing conditions base compared to the FWO. All alternatives provide more alligator habitat suitability compared to the FWO, with alternative 1 providing the most in WCA 3A, alt.3 the most in WCA 3B, and alt.4 the most in ENP. All of the alternative plans improve alligator habitat in northern WCA 3A and the Miami Canal zone by as much as 20% because of new water delivery to northern WCA 3A. Gains are smaller in central WCA 3A, WCA 3B and ENP north and south zones with modest variation regarding which alternative best improves scores. Changes to WCA 3A south and ENP southeast are negligible. When scores are aggregated by water conservation area, the trends are similar, but lifts are compressed by aggregation over a larger area. In addition, WCA 2 has a 5% loss of habitat suitability resulting from water being redirected from WCA 2 to WCA 3A for all alternatives.

Table 5-2. Cumulative Alligator Habitat Suitability index

Zone	ECB Lift	ALT1 Lift	ALT2 Lift	ALT3 Lift	ALT4 Lift
3A-C	0.523023	2.667964	1.906198	1.744549	1.924805
3A-MC	0.961123	8.801647	8.403512	8.369291	8.429125
3A-NE	0.634494	6.976743	8.001702	7.972184	8.022031
3A-NW	0.159704	6.258332	5.46354	5.459678	5.467471
3A-S	0.230372	0.755098	0.065521	-0.46596	0.254751
3B	1.286395	2.147014	2.744168	4.231454	1.608658
ENP-N	0.267711	0.550803	1.152958	1.77616	2.394573
ENP-S	-0.16428	1.750491	1.578731	2.387581	2.464859
ENP-SE	0.020763	0.161189	0.137693	0.22291	0.190128

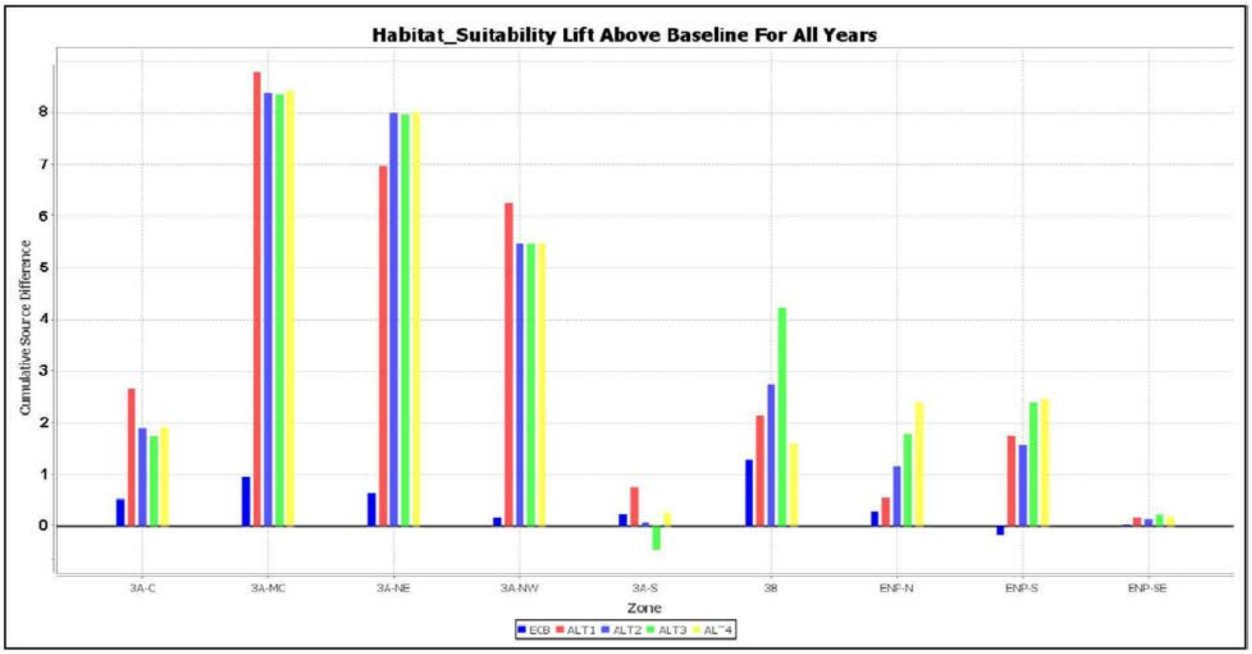


Figure 5-14. Cumulative Alligator Habitat Suitability Index Scores by Region

Freshwater Fish Densities

J. Trexler and C. Catano (2013) used a parameterized logistic model to predict small fish densities based on the time between drying events. In all regions directly south of the L-5 canal (WCA 3A, WCA 3B, Shark River Slough, Southern Marl Prairies, and Taylor Slough) the CEPP models predicted fewer drying events than either the ECB or FWO, leading to greater days since last drydown and higher daily fish density throughout the 41-year period of record. The percent difference in average fish density between the CEPP models and baseline models was always higher when compared to 2050 than when compared to ECB. **Figures 5-15, 5-16, 5-17, and 5-18** maps compare the average smallfish (< 8 cm, e.g., mosquitofish) density the alternatives to the FWO across the Greater Everglades Landscape. The map on the left is the FWO, right is the CEPP alternative being compared, and the middle map is the difference between them, where green is positive increase, yellow is little to no chance, and red is decreased density. The size of the circle represents a greater % change. In general, all alternatives increased fish density in Northern WCA 3A, slightly in 3B, and also in ENP. **Table 5-3** provides the percent change in fish density on average in each GE area between the CEPP alternatives and ECB, FWO baselines. The largest percent gains in daily average fish density were generally predicted for northern WCA 3A and northeast Shark River Slough. In these areas, fish densities often increased in excess of 30%, with extremes of over 80%. Scaled up in space and time, this translates to a very large increase in biomass. A key point is that large areas of fish biomass are concentrated in the dry season, so modest per-meter-square increases in wet-season biomass have the potential to increase bird food availability in a geometric fashion. The regional percent changes in fish densities were highest in Shark River Slough (16% - 23%) and Southern Marl Prairies (17% - 31%) compared to the FWO. Alternatives 3 and 4 generally had the largest percent increases and were comparable in magnitudes. In addition, **Table 5-4** provides the percent change in large fish density (largemouth bass (Micropterus salmoides)) on average in each Greater Everglades (GE) area between CEPP alternatives 1-4 and the ECB, FWO baselines. All alternatives increase large fish density in the landscape, but alternatives 1 and 2 show the most increase in the southern marl prairie (SMP), whereas alternative 2 does the best in 3B, alternative 4 is best in Shark River Slough (SRS). Taylor Slough (TS) and WCA 2A show decreases in largemouth bass density compared to the FWO. However, those decreases are far less than the percent increases seen in other areas due to the CEPP alternatives

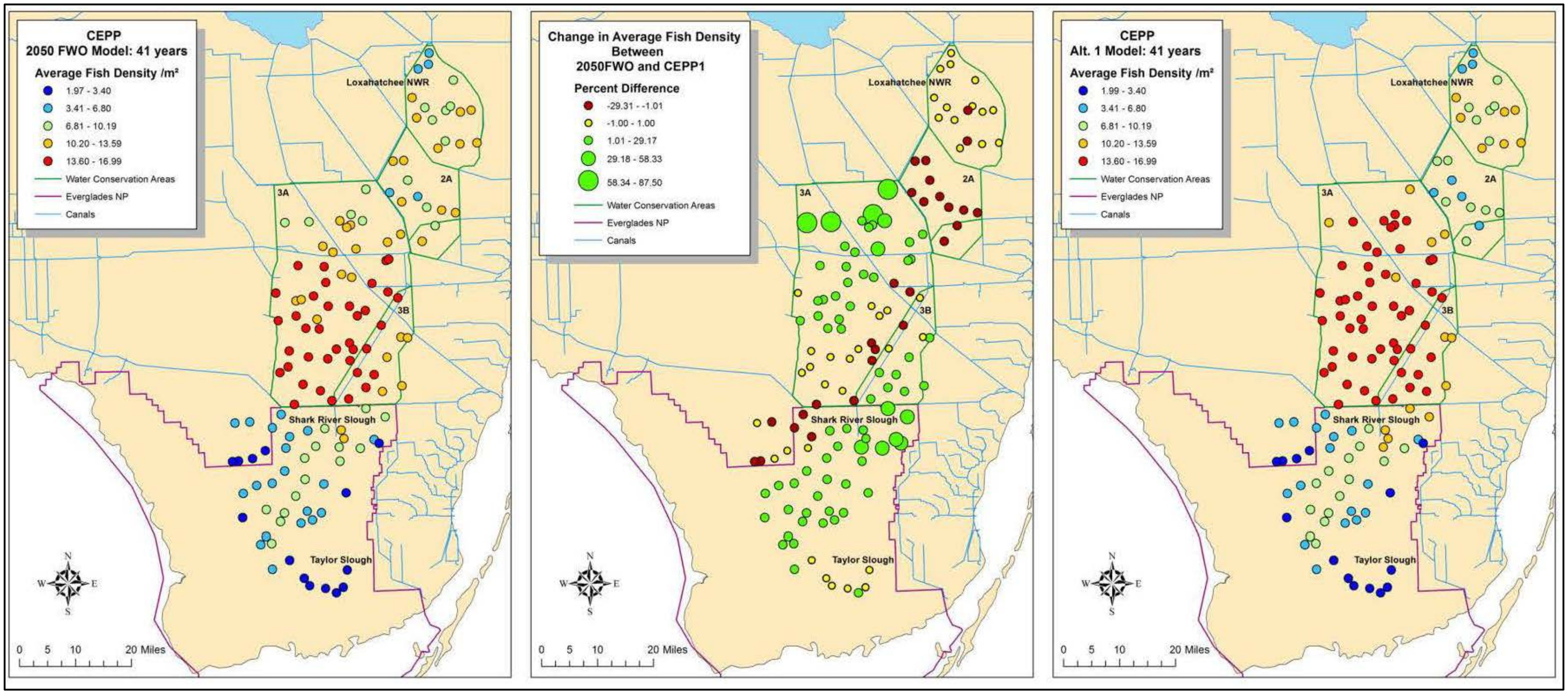


Figure 5-15. Alternative 1 Small Fish Performance

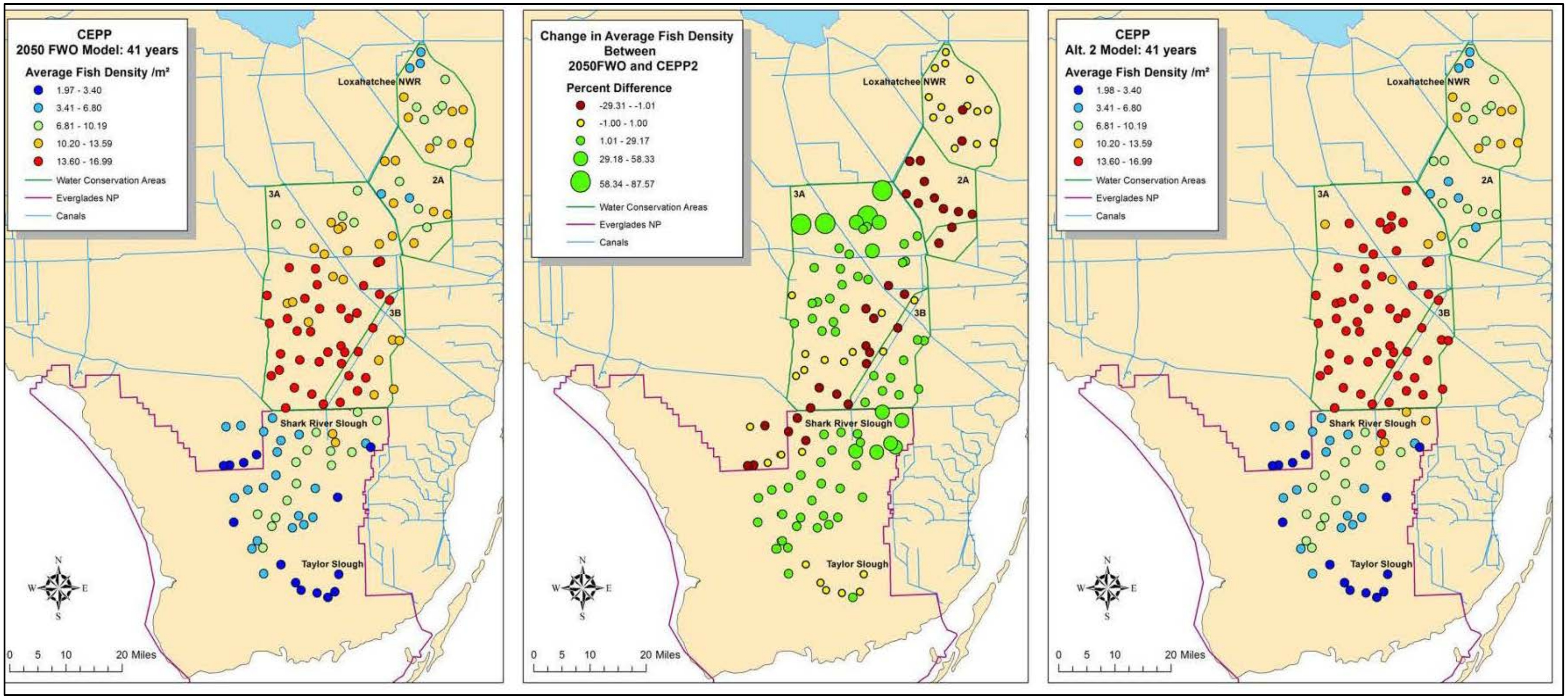


Figure 5-16. Alternative 2 Small Fish Performance

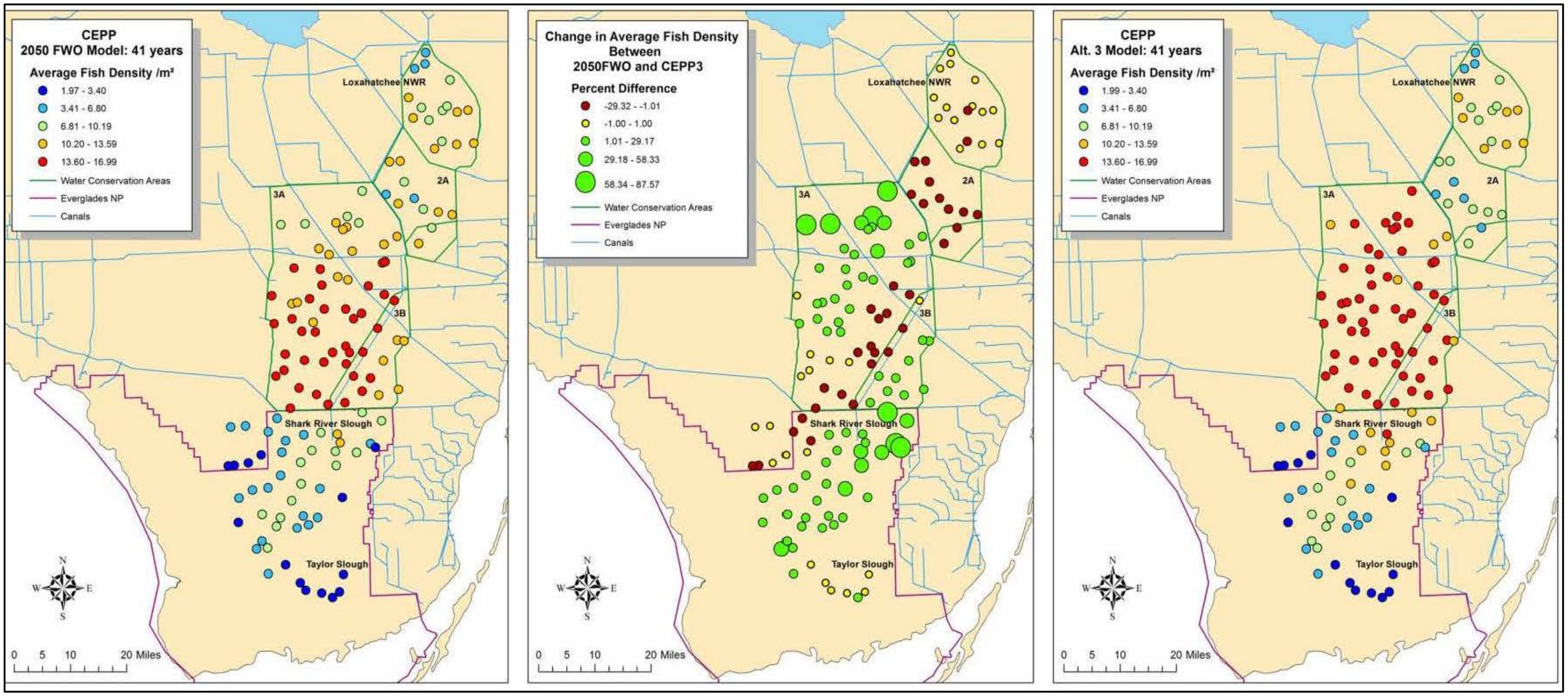


Figure 5-17. **Alternative 3 Small Fish Performance**

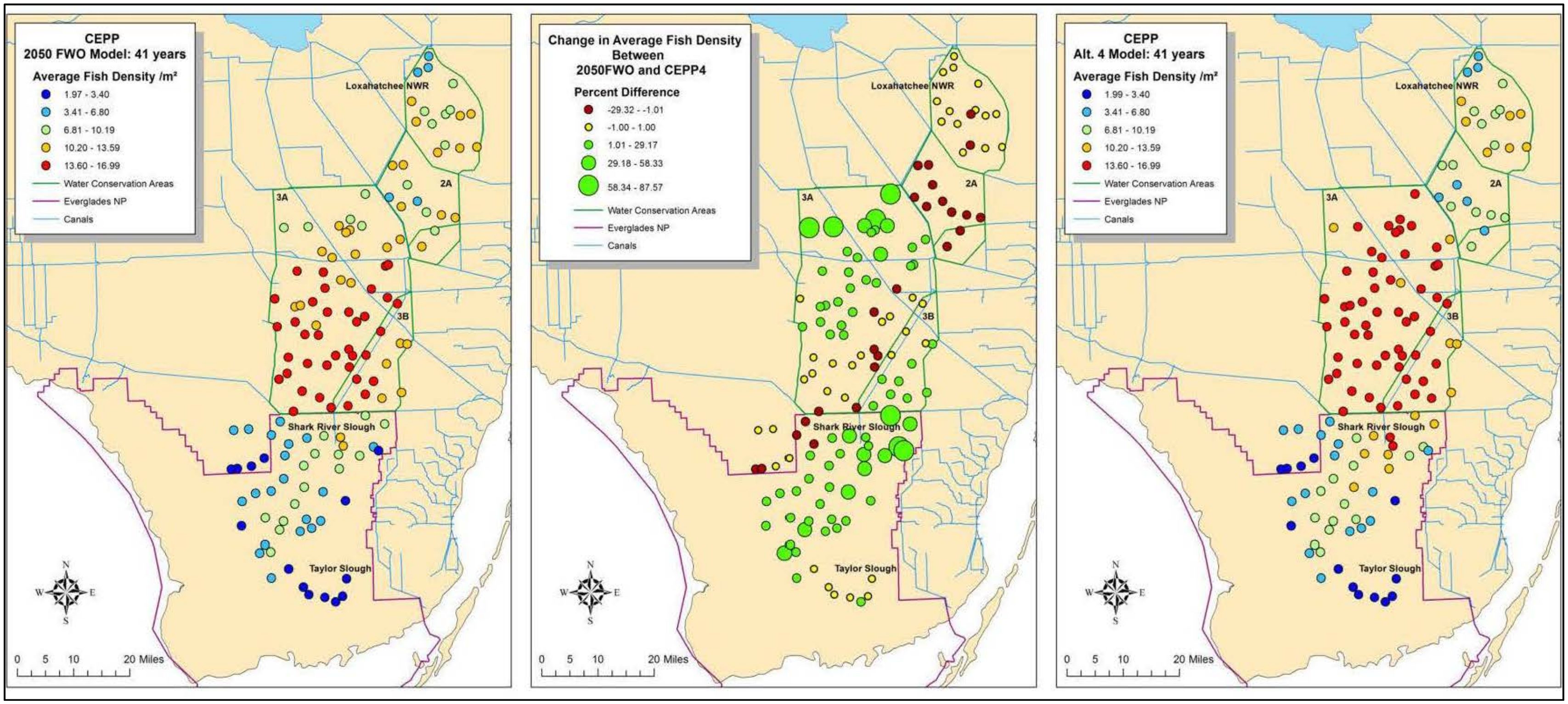


Figure 5-18. Alternative 4 Small Fish Performance

Table 5-3. CEPP Alternative Small Fish Density per Meter Squared

Region	CEPP1		CEPP2		CEPP3		CEPP4	
	ECB	2050FWO	ECB	2050FWO	ECB	2050FWO	ECB	2050FWO
2A	**0.70**	-12.96	**0.70**	-12.96	**0.70**	-12.96	**0.71**	-12.95
3A	**5.46**	**9.36**	**4.75**	**8.62**	**4.46**	**8.31**	**5.20**	**9.08**
3B	-0.43	**4.87**	**2.59**	**8.04**	**1.25**	**6.64**	-1.30	**3.96**
LOX	-2.71	-0.46	-2.71	-0.46	-2.71	-0.46	-2.71	-0.46
SMP	**16.05**	**18.42**	**14.85**	**17.20**	**28.65**	**31.28**	**27.45**	**30.05**
SRS	**13.39**	**16.04**	**13.64**	**16.30**	**18.66**	**21.44**	**20.48**	**23.30**
TS	**0.04**	**0.55**	-0.11	**0.39**	**0.05**	**0.56**	-0.01	**0.49**

Alternatives 3 and 4 provided a greater percent increase in fish density in ENP than alternatives 1 and 2, and all alternatives produce less fish in WCA 2 compared to the FWO.

Table 5-4. CEPP Alternatives Large Fish Density per Meter Squared

Region	CEPP1		CEPP2		CEPP3		CEPP4	
	ECB	2050FWO	ECB	2050FWO	ECB	2050FWO	ECB	2050FWO
2A	-51.57	-53.07	-52.94	-54.40	-51.91	-53.40	-51.39	-52.90
3A	**24.50**	**54.14**	**6.77**	**32.18**	**21.22**	**50.08**	**11.66**	**38.23**
3B	**28.96**	**146.04**	**61.28**	**207.70**	**25.06**	**138.60**	**6.79**	**103.74**
LOX	-26.63	-14.94	-27.00	-15.36	-26.94	-15.29	-26.52	-14.81
SMP	**805.52**	**785.30**	**886.49**	**864.47**	**470.28**	**457.55**	**386.24**	**375.38**
SRS	**15.04**	**13.33**	**15.47**	**13.76**	**68.91**	**66.41**	**94.15**	**91.27**
TS	-64.10	-35.25	-53.63	-16.36	-69.97	-45.84	-47.08	-4.56

Apple Snail Population

The apple snail population model looks at water depths and temperatures to estimate adult apple snail numbers for each alternative plan (Romanach, S., et al., 2013). All four alternative plans provide better conditions for apple snail populations compared to the FWO. All four alternative plans lead to increased apple snail populations in northern WCA 3A. Alternatives 3 and 4 suggest that they could provide appropriate conditions for getting more apple snails into Everglades National Park compared to alternatives 1 and 2.

Figure 5-19 provides map comparisons of apple snail habitat suitability index values between each CEPP alternative and the FWO. All four alternatives should provide better conditions for apple snail populations compared to Future Without restoration (FWO) in Northern and Central WCA 3A, 3B, and ENP. Slight decreases in apple snail habitat suitability were observed in WCA 2.

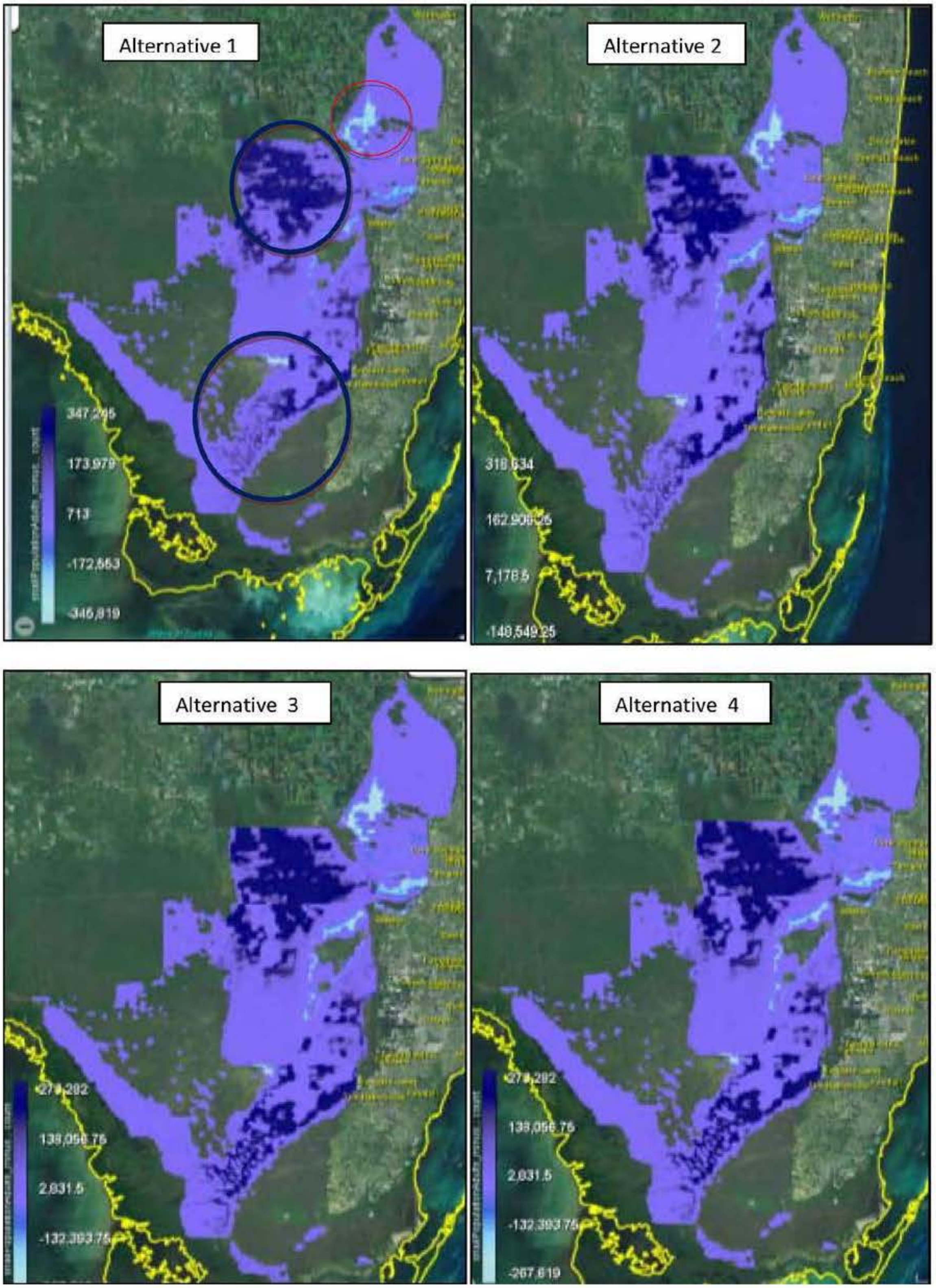


Figure 5-19. Apple Snails ((*Pomacea paludosa*) Habitat Suitability Index

Wading Birds

Several models of wading birds were used to support the overall GE evaluation: 1) Wood Stork Foraging Probability Index model by Everglades National Park; 2) wading bird species distribution model by James Beerens; and 3) wading bird nesting success by Gawlik, et al., 2013.

The Wood Stork Foraging Probability Index (STORKI v. 1.0) was developed to provide rapid simulations of wood stork foraging conditions in response to modeled CERP scenarios (LoGalbo, et al., 2012). **Figure 5-20** below displays woodstork foraging habitat suitability cumulatively over the 41 year period of record for each alternative compare to the FWO for wood storks. Woodstork foraging habitat suitability indicates that all alternatives performed between 70% to 130% better than the FWO foraging habitat in northeast WCA 3A and around the Miami Canal. Alternative 3 and 4 provided 50% to 68% more foraging habitat in WCA 3B and southern ENP. However, all alternatives performed worse in northern ENP (-85%) and WCA 3A South (up to -20%).

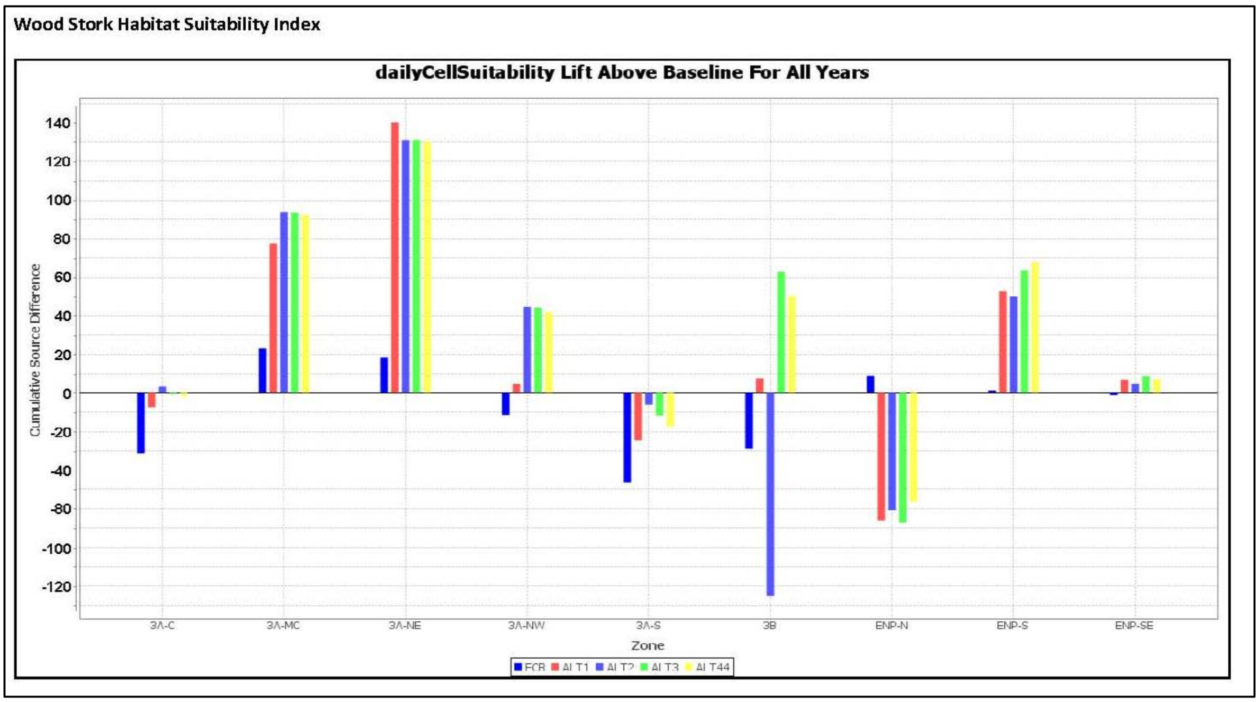


Figure 5-20. **Wading Bird Nesting Models (Great Egret, White Ibis, and Wood Stork)**

Wood stork, white ibis and great egret species distribution were modeled by James Beerens, et al., 2013 in support of the Greater Everglades ecological evaluation (see **Figures 21, 22, and 23** below). Wood storks generally showed increased numbers in northern WCA 3A and southern ENP for the four alternatives compared to the FWO. White ibis numbers were also greater in northern WCA 3A and southern ENP, but also in part of central WCA 3A for all alternatives. The great egret model showed improvements in northern WCA 3A, southern ENP, Central WCA 3A, and WCA 3B, but also indicated reductions in presence in northern ENP.

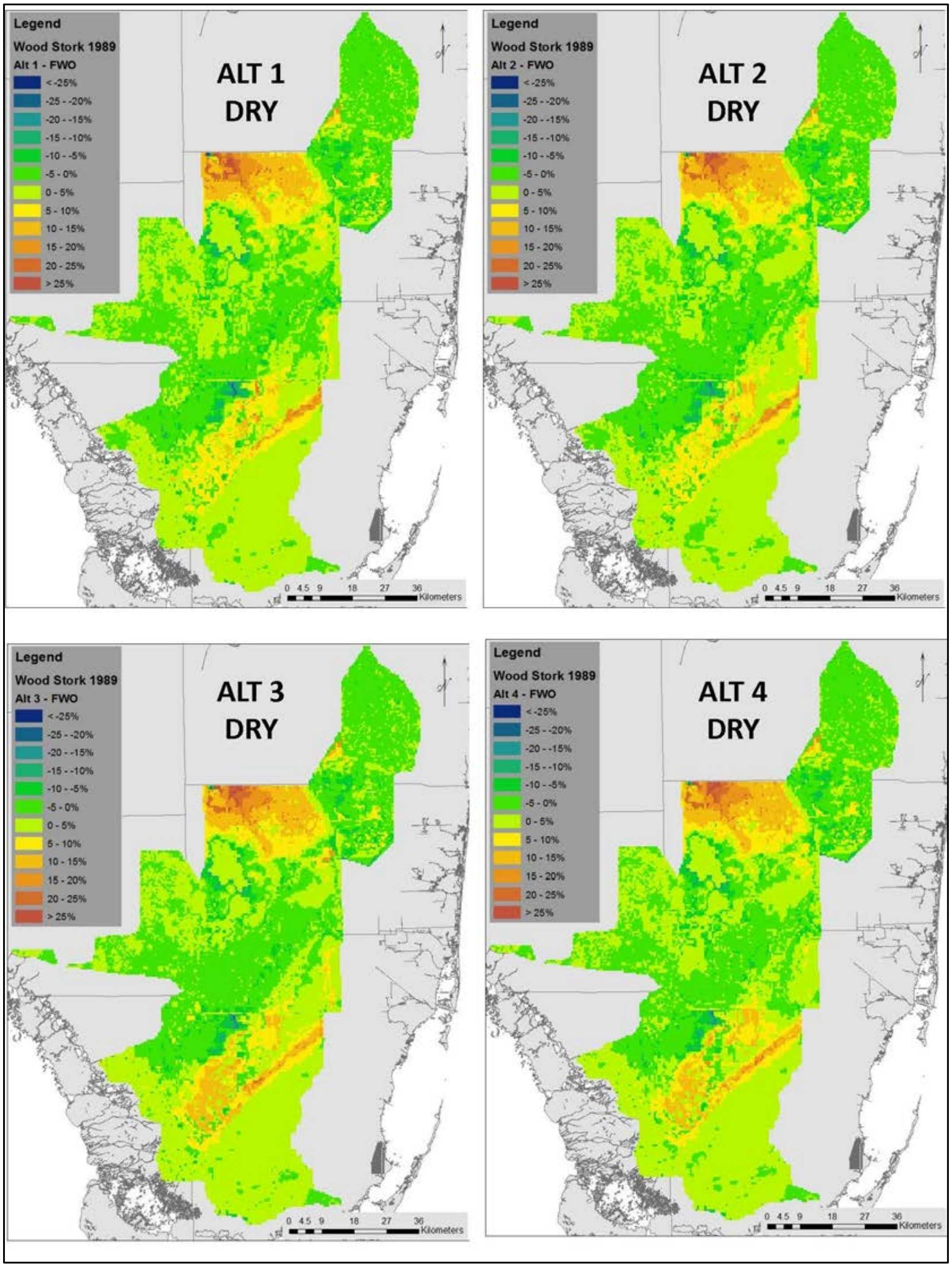


Figure 5-21. **Wood Stork Distribution Dry Year (1989)**

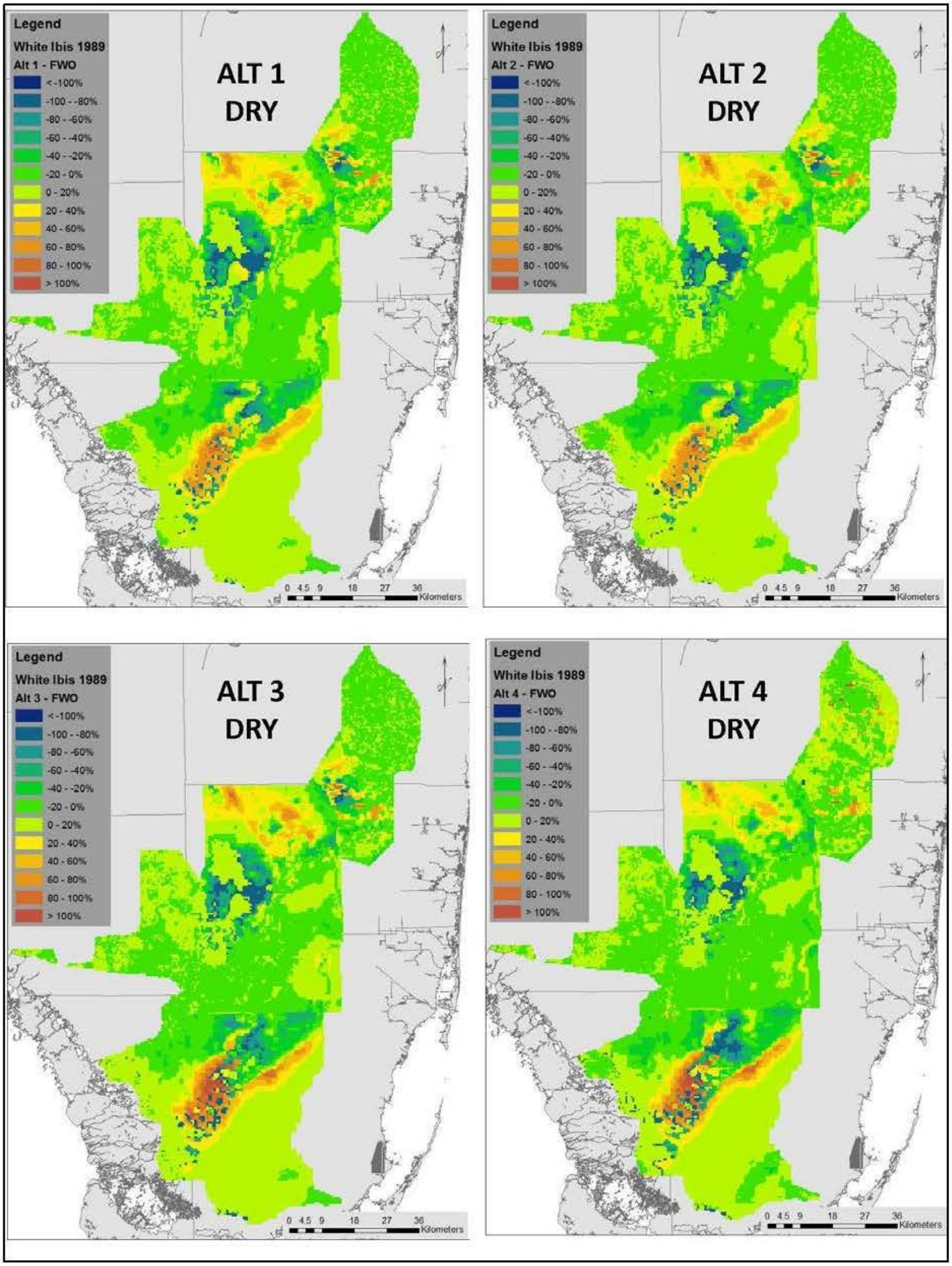


Figure 5-22. White Ibis Distribution Dry Year (1989)

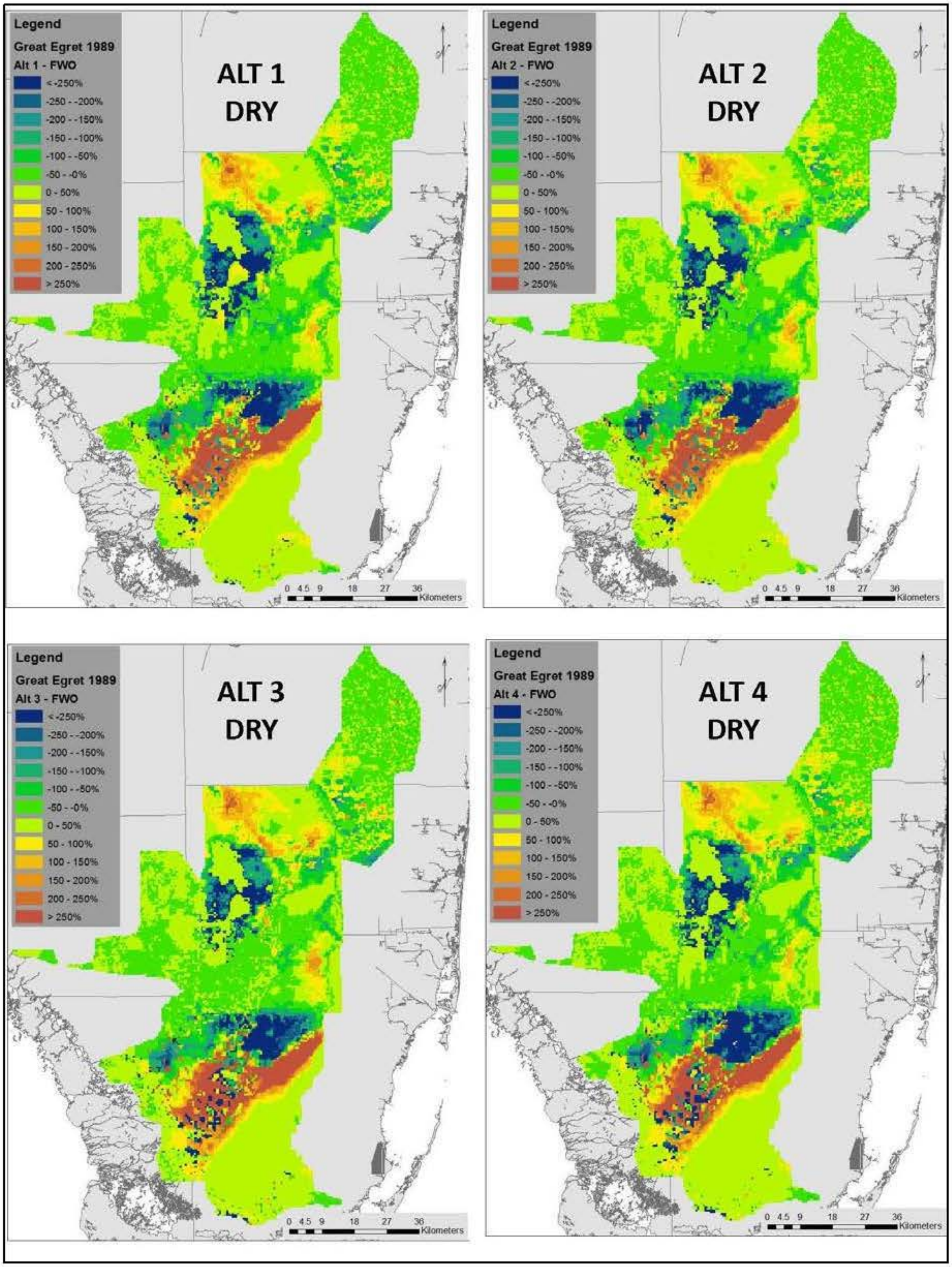


Figure 5-23. Great Egret Distribution Dry Year (1989)

The wading bird nesting models predict the number of nests for the wood stork, white ibis, and great egret species for each alternative (Gawlik, et al., 2013). All four alternatives generally performed better for great egret, white ibis, and wood stork nesting than the FWO. In the northern Everglades each alternative showed less nests than FWO for ibis and storks, but more nests than FWO for egrets. However, in the southern Everglades, the alternatives performed better than FWO. The Great Egret nesting model showed the biggest benefit in raw numbers of nests but the Wood Stork model showed a more significant benefit relative to its population size (Gawlik, et al., 2013). This pattern of better wading bird nesting in the Southern Everglades than Northern Everglades is not unexpected and is consistent with the prediction that nesting trends in a restored Everglades would increase in the coastal zone, rather than system wide (RECOVER, 2009). **Figure 5-24** on the next page displays wading bird nesting results cumulatively over the 41 year period of record for each alternative compare to the FWO for wood storks. In the Southern Everglades alternative 3 performed best for white ibis and great egret, whereas alternatives 1 and 2 performed best for storks. In the wood stork model case, alternative 4 produced about half as many nests above FWO, as did any other alternative.

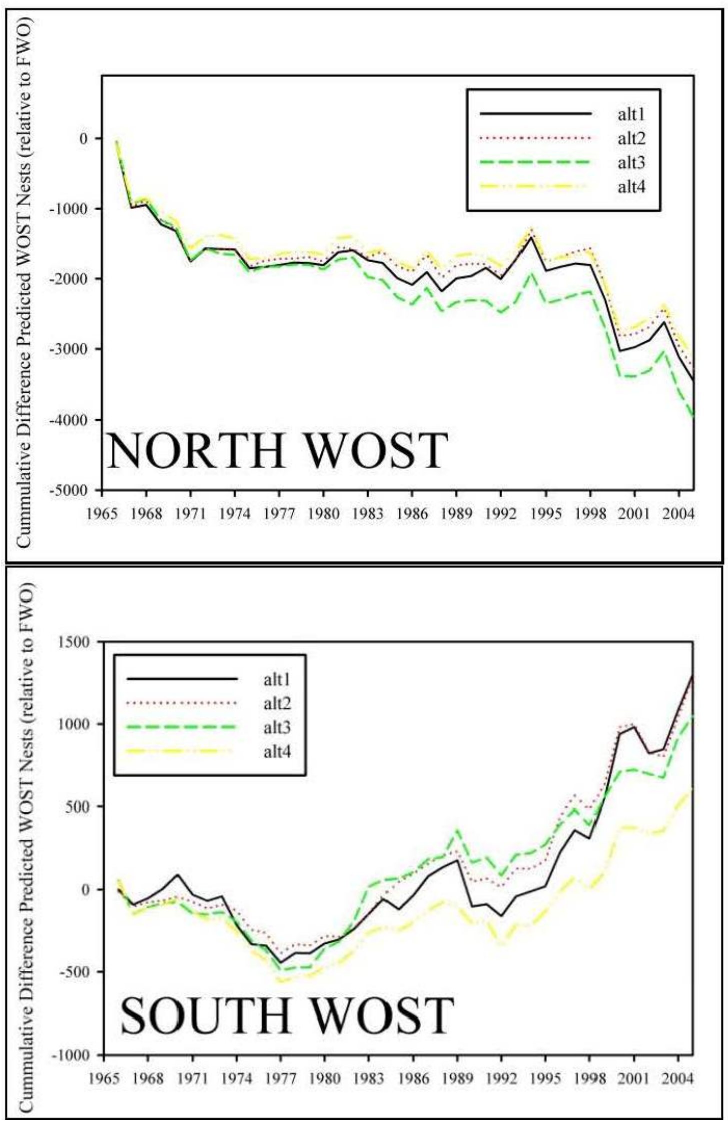


Figure 5-24. **Wading Bird Nesting Models (Great Egret, White Ibis, and Wood Stork)**

5.4 References

Beerens, J.M., Gawlik, D.E., Herring, G. and M. I. Cook. 2011. Dynamic habitat selection by two wading bird species with divergent foraging strategies in a seasonally fluctuating wetland. Auk, 128, 651-662.

Beerens, J. A., E. Noonburg, and D. E. Gawlik. 2012. Greater Everglades Aquatic Trophic Levels DRAFT Wading Bird Landscape Productivity Performance Measure, "WADEM: Wader Distribution Evaluation Modeling". Report to RECOVER for Greater Everglades regional evaluation. Documentum links: https://www.cerpzone.info/webtop/drl/objectId/09009f5c8093f106; https://www.cerpzone.info/webtop/drl/objectId/09009f5c8093f105; and https://www.cerpzone.info/webtop/drl/objectId/09009f5c8093f104.

Botson, B.A. 2012. Mechanisms that generate resource pulses and drive wading bird nesting in a fluctuating wetland. MS thesis, 111 pp., Florida Atlantic University, Boca Raton, FL.

Brandt, L.A. and F.J. Mazzotti. 2000. Nesting of the American alligator (Alligator mississippiensis) in the Arthur R. Marshall Loxahatchee National Wildlife Refuge. Florida Field Naturalist. 28(3):122-126.

Cook, M.I., and M. Kobza, eds. 2010. South Florida Wading Bird Report. South Florida Water Management District, West Palm Beach, Florida. Vol. 16: 1- 43. http://my.sfwmd.gov/portal/page/portal/xrepository/sfwmd_repository_pdf/wadingbirdreport2010.pdf. Date obtained online: 17 February 2012.

Craighead, F.C. 1968. The role of the alligator in shaping plant communities and maintaining wildlife in the southern Everglades. Fla. Nat., 41:2-7, 69-74, 94.

Crozier, G.E. and D. E. Gawlik. 2003. Wading Bird Nesting Effort as an Index to Wetland Ecosystem Integrity. Waterbirds, 26, 303-324.

Catano, C. and J. Trexler. 2013. CEPP model comparison of predicted freshwater fish densitites. Draft report to RECOVER for Greater Everglades regional evaluation. Documentum link: https://www.cerpzone.info/webtop/drl/objectId/09009f5c8093f103

DeLeo, J.M. 1993. Receiver operating characteristic laboratory (ROCLAB): Software for developing decision strategies that account for uncertainty. Uncertainty Modeling and Analysis, 1993. Proceedings., Second International Symposium on, pp. 318-325.

Donalson, D., J. Trexler, D. DeAngelis, and A. Logalbo. 2010. Prey-based freshwater fish density performance measure (Greater Everglades aquatic trophic levels). DECOMP Performance Measure, Documentation Sheet.

Frederick, P., D.E. Gawlik, J.C. Ogden, M.I. Cook, and M. Lusk. 2009. The White Ibis and Wood Stork as indicators for restoration of the everglades ecosystem. Ecological Indicators, 9, S83-S95.

Gawlik, D.E., B.A. Botson, and M.L. Peterson. 2013. Predicted wading bird nest effort for the Central Everglades Planning Project (CEPP) alternatives. Draft report to RECOVER for Greater Everglades regional evaluation. Documentum link: https://www.cerpzone.info/webtop/drl/objectId/09009f5c8093f102

Kushlan, J.A. 1990. Wetlands and wildlife, the Everglades perspective in Freshwater wetlands and Wildlife, R. R. Sharitz and J. W. Gibbons (Eds.), CONF-8603101, DOE Symp. Ser. No. 61, Office of Scientific and Technical Information, U.S. Department of Energy, Oak Ridge Tenn.

LoGalbo, Alicia, L. Pearstine, J. Lynch, R. Fennema, and M. Supernaw. 2012. Wood Stork Foraging Probability Index (STORKI v. 1.0) Ecological and Design Documentation. http://www.cloudacus.com/simglades/docs/WoodStorkEcologicaldoc_20120601.pdf

Ogden. John C. 1994. A comparison of wading bird nesting colony dynamics (1931-1946 and 1974-1989) as an indication of ecosystem conditions in the southern Everglades in, "Everglades the Ecosystem and its Restoration", eds,. Davis, S.M. and J.C. Ogden. pps. 533- 570.

Pearlstine, L., S. Friedman, and M. Supernaw. 2011. Everglades Landscape Vegetation Succession Model (ELVeS) Ecological and Design Document: Freshwater Marsh & Prairie Component version 1.1. South Florida Natural Resources Center, Everglades National Park, National Park Service, Homestead, Florida. 128 pp. http://www.cloudacus.com/simglades/docs/ELVES%20freshmarsh%20Ecological%20Doc_v1-1_30July2011.pdf

Pearlstine, L., A. LoGalbo, and G. Reynolds. 2013. Marl Prairie Indicator Scores documentation report. http://www.cloudacus.com/simglades/docs/Marl%20Prairie%20Indicator%20scoring06jan2012.pdf

RECOVER, 2009. Monitoring and Assessment Plan – Greater Everglades Wading Bird Nesting in the Mainland and Coastal Everglades in Relation to the Aquatic Fauna Forage Base Hypothesis Cluster. http://www.evergladesplan.org/pm/recover/recover_map_2009.aspx

RECOVER, 2011. Prey-based freshwater fish density performance measure. Restoration Coordination and Verification Program c/o U.S. Army Corps of Engineers, Jacksonville, FL, and South Florida Water Management District, West Palm Beach, FL. http://www.evergladesplan.org/pm/recover/recover_docs/perf_measures/ge_pp_fish_pm_051611.pdf

Romanach, S., P. Darby, D. DeAnglis. 2013. Draft Apple snail population model report to RECOVER for Greater Everglades regional evaluation. Documentum link: https://www.cerpzone.info/webtop/drl/objectId/09009f5c8093f385

Shinde, D., L. Pearlstine, L.A. Brandt, F.J. Mazzotti, M. Parry, B. Jeffery, and A. LoGalbo. Draft. Alligator Production Probability Index Model (GATORPI v. 1.0) Ecological and Design Documentation. http://www.cloudacus.com/simglades/docs/Alligator_Production_Ecologicaldoc_releaseV1.0_DRAFT.pdf.

Swets, J.A. 1988. Measuring the Accuracy of Diagnostic Systems. Science, 240, 1285-1293.

6 SOUTHERN COASTAL SYSTEMS REGIONAL REPORT

RECOVER System-wide Regional Evaluation

Central Everglades Planning Project

Southern Coastal System Regional Coordinators: Susan Kemp – USACE, Dave Rudnick – ENP, Patrick Pitts – USFWS

Acknowledgements: The Southern Coastal Systems Regional Coordinators thank the following Principal Investigators and technical staff for their contributions to this report: Mr. Rick Alleman (SFWMD), Dr. Laura Brandt (USFWS), Dr. Joan Browder (NOAA-NMFS), Dr. Chris Kelble (NOAA-AOML), and Dr. Chris Madden (SFWMD).

6.1 Executive Summary

The Southern Coastal Systems region covers a network of estuaries on the southern end of Florida including Biscayne Bay, Florida Bay, and the lower southwest Florida coastal systems. The summary for the RECOVER system-wide evaluation of Central Everglades Planning Project (CEPP) is provided in the following list of key findings:

1. Flow increases in major sloughs providing freshwater to Florida Bay are predicted for all CEPP alternatives compared to the Future Without Project (FWO) condition. Flows at Transect 27 in Shark River Slough indicate significant increases (195K to 262K ac-ft/yr) for all alternatives compared to FWO, with alternative 4 providing the largest increase. However, flow analyses at Transect 23A in Taylor Slough indicate only a slight increase (2-3K acre-feet/year) in flows above FWO for all alternatives, but almost no difference between alternatives.
2. The Florida Bay salinity performance measure shows lift from all alternatives over FWO, with generally modest differences between alternatives compared to FWO or Existing Condition Baseline (ECB). The overall ranking of alternatives based on the performance measure is: alternative 4>alternative 3>alternative 1>alternative 2.
3. Spotted seatrout, pink shrimp, and crocodile habitat suitability indices and submerged aquatic vegetation (SAV) simulation model results show noticeable lift from all alternatives relative to FWO. However, differences between alternatives are modest and not statistically significant for seatrout, and may not be statistically significant for pink shrimp, crocodiles and SAV. The trend in the habitat suitability index (HSI) and SAV model data indicate that alternative 4 provides the most lift compared to the other alternatives.
4. Given the linkages between Shark River Slough flow and salinity in Florida Bay, it is likely that benefits to the lower southwest Florida coastal estuaries (e.g. Whitewater Bay) may show greater lift than the models predict for Florida Bay.
5. There are general reductions in flow at most coastal structures in central and southern Biscayne Bay from FWO and CEPP alternatives compared to ECB, and there are flow reductions from most CEPP alternatives compared to FWO in these regions.
6. There is no change or increase in flows through the northern Biscayne Bay coastal structures from FWO and CEPP alternatives compared to ECB.
7. At the coastal structures that show reductions in flow compared to FWO, reductions are generally greater during the dry season.
8. Overall ranking of alternatives based on flows and the salinity performance measure at the Biscayne Bay coastal structures is the opposite of the Florida Bay salinity ranking: alternative 2>alternative 1>alternative 3>alternative 4.
9. Flow at the three divide structures (S-338, S-194, S-196) that provide freshwater flow from the Everglades to south Biscayne Bay shows substantial reductions for all alternatives compared to FWO. Compared to FWO, reductions at S-338 are generally greater during the dry season; whereas, the opposite seasonal pattern is exhibited for the S-194 and S-196.
10. We have concerns that the model-predicted reductions in flows at the divide structures and the central and southern Biscayne Bay coastal structures may negatively impact the ecological status of Biscayne National Park and restoration progress of CERP's Biscayne Bay Coastal Wetland Project.

6.2 Introduction

The CERP Southern Coastal Systems (SCS) region encompasses a network of estuaries on the southern end of Florida which require fresh water inputs from upstream to maintain ecologically favorable brackish salinity conditions. Over the last century, water management and land development activities have resulted in inadequate volume, timing, and distribution of freshwater flows to these estuaries, changing the salinity regime in the estuaries and resulting in ecological degradation compared to conditions prior to water management. Preliminary analyses of modeling output from sensitivity runs indicated that the Central Everglades Planning Project (CEPP) project alternatives may increase flows to and improve salinity conditions in the SCS. This report evaluates effects of the CEPP final array of alternatives on flow, salinity, and ecological conditions in the SCS. The evaluation compares alternatives primarily against the "future without project" (FWO) condition and, where relevant, to the "existing condition baseline" (ECB) or the "target" condition for Florida and Biscayne Bays.

6.3 Evaluation Methods

The evaluation relies on Regional System Model (RSM) output of stage and flow in the southern part of the model domain. Analyses are performed on RSM model output for flow at select transects in the Everglades National Park that provide freshwater to Florida Bay and at select water management structures that feed freshwater to Biscayne Bay. Additionally, RSM model output for stage at select gage locations in the southern part of the model domain is converted to salinity using multi-linear regressions (paleo-adjusted MLRs) at salinity monitoring locations in Florida Bay for evaluation in the bay as described below. Salinity is evaluated directly and also used as input to habitat suitability indices, also described below.

Florida Bay

For the Florida Bay evaluation, flows across Transect 23A in Taylor Slough and Transect 27 in Shark River Slough were examined to provide information on freshwater flows to Florida Bay. The RECOVER Florida Bay salinity performance measure was used and habitat suitability indices (HSIs) for juvenile spotted seatrout, pink shrimp, juvenile crocodiles and an SAV simulation model applicable to Florida Bay were quantified.

<u>Salinity Performance Measure</u>

The Florida Bay salinity performance measure (RECOVER_a, 2012) used in the evaluation was approved for use by RECOVER in June 2012. Daily salinity values for the 1965-2005 period for 17 bay stations (via RSM and MLR models) were provided as input to the performance measure by the IMC for all CEPP alternatives, ECB, and FWO. The IMC-provided NSM daily salinities were not used to determine the restoration target because the required paleoecological adjustment was not applied, so a previously run paleo-adjusted NSM output data set with a 1965-2000 period of record was used to set the restoration target. The IMC-provided daily salinity values for CEPP alternatives, ECB, and FWO were truncated to match the restoration target period of record (1965-2000). The performance measure consists of three metrics—regime overlap, mean offset, and high-salinity metric—and are defined as follows:

- *Regime overlap metric* – examines the central tendency of salinity distributions by comparing the overlap between the mid-ranges of the target and the observed or predicted (CERP alternative) time series. The mid-range is defined as the salinity range between the 25th and 75th percentiles.

- *Offset metric* - provides a measure of the magnitude that the CEPP alternative may deviate from the target. It is determined by calculating absolute value of the difference between the target monthly (or seasonal) salinity mean and the predicted monthly (or seasonal) salinity mean.
- *High salinity* – estimates frequency of harmful high salinity and is calculated as frequency of salinity exceeding NSM 90th percentile, relative to frequency expected with NSM (thresholds are MMN station specific).

Each metric was calculated for wet and dry seasons and output was reported as bay zone averages. See **Figure 6-1** for locations of the 17 salinity stations and bay zones.

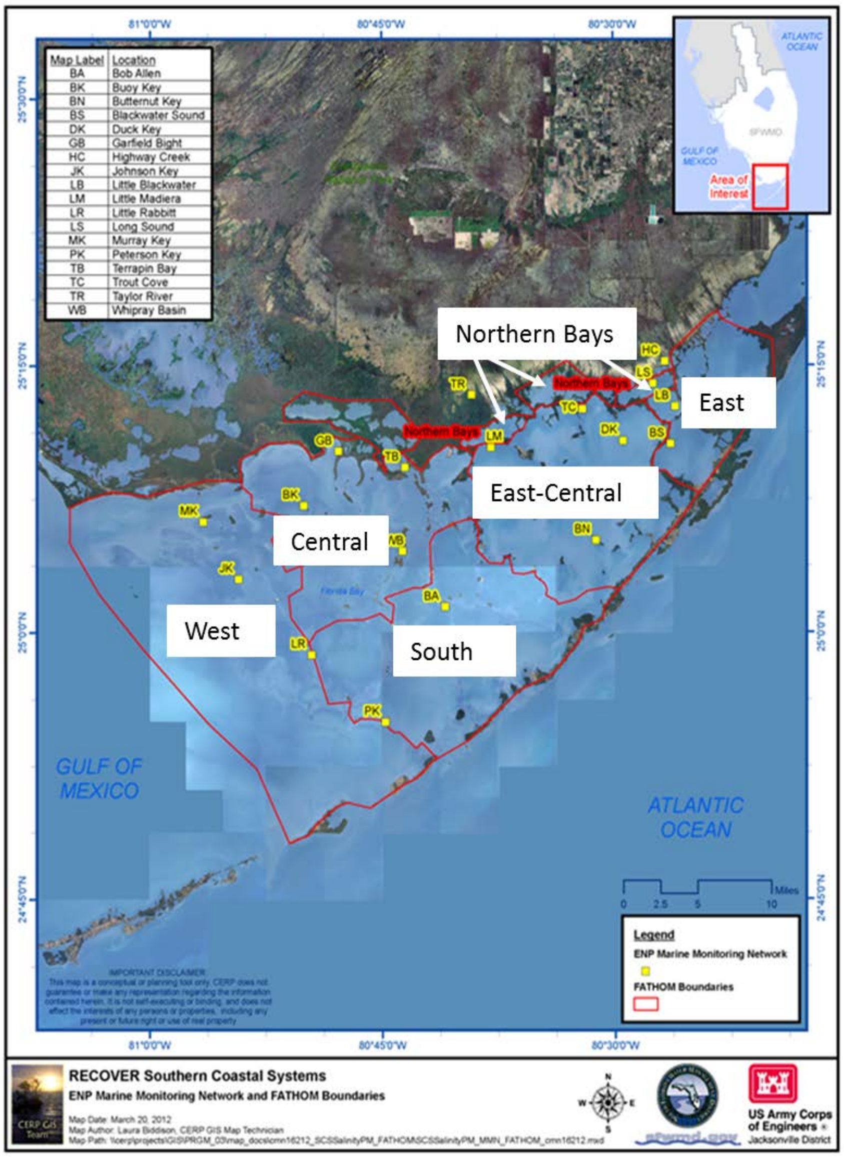


Figure 6-1. **Map showing salinity stations (yellow squares) and six bay zones used in the Florida Bay salinity performance measure analyses.**

Other Information Sources - Habitat Suitability Indices and Submerged Aquatic Vegetation (SAV) Simulation Model

Juvenile Crocodiles – The crocodile (*Crocodylus acutus*) growth and survival index used in this analysis is one of the components of a crocodile HSI that characterizes suitable habitat for crocodiles based on habitat, location of known nest sites, salinity, and prey biomass. The growth and survival index is calculated for August through December, the period following hatching when hatchlings are most vulnerable to high salinities (Moler 1992; Mazzotti 1999; Mazzotti et al. 2007). For this analysis, data from the salinity monitoring stations at Joe Bay, Trout Cove, Little Madeira Bay (the stations among the available stations closest to where the highest densities of crocodile nests are) and Long Sound, Little Blackwater Sound, Terrapin Bay and Garfield Bight (generally closer to shoreline stations in areas where crocodiles could occur) are used as input to the HSI. Each day from August 1-December 31 is assigned a score based on the following salinity ranges: salinity <20 psu was assigned the highest score of 1 because salinity in this range is considered most favorable for juvenile crocodile growth and survival (Moler 1992; Mazzotti 1999; Mazzotti et al. 2007); salinity between 20 psu to <30 psu was assigned a score of 0.6; 30 psu to <40 psu a score of 0.3, and >40 psu a score of 0. Average yearly and an average overall score were calculated.

Juvenile Spotted Seatrout – The spotted seatrout (*Cynoscion nebulosus*) HSI is a qualitative model that uses a logistic regression to assess how the frequency of occurrence of juvenile spotted seatrout varies in response to environmental parameters (turbidity, temperature, salinity, and spatial coverage and density of three species of seagrass) (RECOVER_b, 2012). The model calculates the area of habitat suitable for juvenile spotted seatrout based on the above parameters. For this exercise, all parameters were held constant except for salinity. For juvenile spotted seatrout, there are five biologically relevant ranges for salinity as determined by the linear response in cumulative frequency of seatrout to salinity. HSI index scores were then calculated by taking the frequency of occurrence for each of these five ranges and dividing by the highest frequency of occurrence for any of the ranges. For example, the range from a salinity of 32 to 39 had the highest frequency of occurrence at 0.255 and received an suitability index (SI) =1 (0.255/0.255); however, the range from a salinity of 40 to 52 had a frequency of occurrence of 0.145 and an SI=0.57 (0.145/0.255).

Pink Shrimp – The pink shrimp (*Farfantepenaeus duorarum*) model simulates growth, survival, and potential harvest of a cohort of shrimp as a function of salinity and temperature (Browder et al. 1999, 2002). Coefficients for functions relating growth and survival to salinity and temperature were based on laboratory experiments on young shrimp collected from Florida Bay and reared under salinities ranging from 2 to 55 and temperatures ranging from 15° C to 33° C. Potential harvest, an indicator of performance, is simulated by starting with a set number of postlarval shrimp (1×10^7) from a hypothetical July cohort and tracking the potential harvest from that cohort for a given year based on the salinity for that year using the CEPP model output for each alternative. The simulation is repeated each year of the model period of record (1965-2005) to produce a time series of growth and survival for a cohort of shrimp entering the bay in a given month. Temperature for each simulation year is daily data from 2007, so temperature is, in effect, held constant.

Submerged Aquatic Vegetation – The SEACOM model (Madden and McDonald 2010), a seagrass community ecological simulation model, determines outcomes of biomass and species composition for three Florida Bay seagrass species—turtle grass (*Thalassia testudinum*), shoal grass (*Halodule wrightii*), and widgeon grass (*Ruppia maritima*). The SEACOM model was initialized as follows: average year conditions (the standard model conditions) for each Florida Bay location were calculated from real salinity, temperature data (Everglades National Park continuous monitoring platforms, computed daily), and water column nitrogen and phosphorus data (SERC FIU marine monitoring network, computed monthly) from 1996 to 2005. The standard salinity and temperature model was calculated as the average value for each Julian day across all years in the period of record (e.g. the Jan 1 value equals the average of values on January 1 from 1996-2005) and the standard nutrient model was calculated as the monthly average for total N and P across 1996-2005. The monthly average value was applied to each day of the month, yielding a step function. SEACOM was equilibrated at each location by initializing with these standard parameter conditions and run with a timestep (dt) of 0.1 day for a 50 year simulation period, by which time SAV values were fully stabilized. The final seagrass values provided by the equilibrated model were applied as initial conditions for each of the scenario runs. For each 40-year scenario run, the salinity simulations were provided from the RSM-MLR output and run with the standard model temperature and nutrients.

Biscayne Bay

<u>Flow at Coastal Structures</u>

For the Biscayne Bay evaluation, flows at the coastal structures were analyzed for all alternatives and compared to FWO and ECB. Structure flows are generally reported as mean annual flows and percent changes of those flows for alternatives relative to ECB and FWO. Also, the RECOVER salinity performance measures developed for select coastal structures (RECOVER, 2008) and currently approved for use by RECOVER were used. These performance measures utilize daily, monthly, or seasonal flow envelope targets at the coastal structures as a proxy for desired salinity conditions in the bay. For example, the performance measure for the S-22 control structure on the Snapper Creek Canal (C-2), which provides freshwater to central Biscayne Bay, has a restoration target flow envelope as follows: the average monthly flow should be maintained between 22,392 acre-feet/month and 50,360 acre-feet/month.

As requested by the CEPP project managers, the Biscayne Bay coastal structure evaluation was performed for four separate bay regions—north, central, south, and Manatee Bay/Barnes Sound **(Figure 6-2**).

Figure 6-2. **Map showing the four regions (red ovals) evaluated for Biscayne Bay.**

Flow at Divide Structures

The accuracy of hydrologic model domains along the boundaries is known to be poorer than in the interior of the domain. The RSM model is no exception. The Biscayne Bay coastal structures are along the boundary of the RSM model, so there is a greater uncertainty in the accuracy of flow output at those structures. Because of this uncertainty, the flows at the divide structures that provide freshwater to the Biscayne Bay coastal basins from the west were also analyzed. The divide structures are located in the interior of the model domain and thus, output from these structures should be more accurate relative to the coastal structure flow output. There are no RECOVER performance measures that apply to divide water control structures.

6.4 Results

Florida Bay

Flow Transects

Figure 6-3 shows flows across Transect 27 in Shark River Slough. All 4 alternatives have greater flows down Shark River Slough toward the coast than the FWO. This flow can directly benefit the southwest coastal wetlands and estuaries (e.g. Whitewater Bay and riverine estuaries). It can less directly benefit Florida Bay via surface water and shallow groundwater flow and by plumes of low salinity water across the bay's western boundary (around Cape Sable). Mean annual flow, mean dry season flow, and wet season flow all have the same ranking among alternatives, as follows: Alt4>Alt3>Alt1>Alt2. Annual flow increases above FWO range from 262,000 acre-ft/y for Alt 4 to 192,000 acre-ft/y for Alt 2. Note that Florida Bay salinity for CEPP is estimated from wetland stage and not flow.

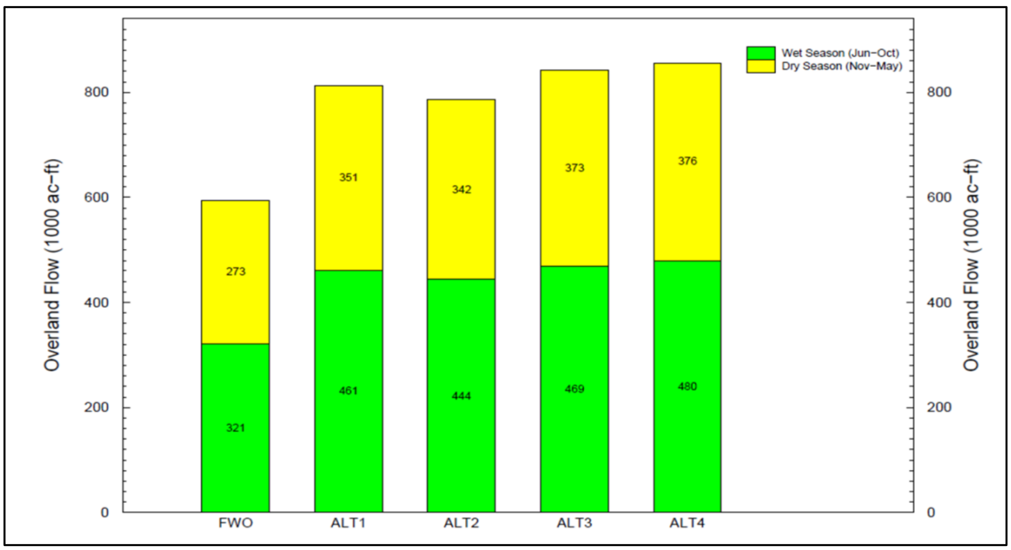


Figure 6-3. **Average annual overland flow across Transect 27 (southwestward flow in central Shark River Slough).**

Figure 6-4 shows average annual overland flow across Transect 23A (one of the 3 flow transects across western Taylor Slough). The plot shows very little difference across alternatives compared to FWO. Alternative 4 has only slightly more dry season flow than other alternatives. The two more easterly transects show similar results.

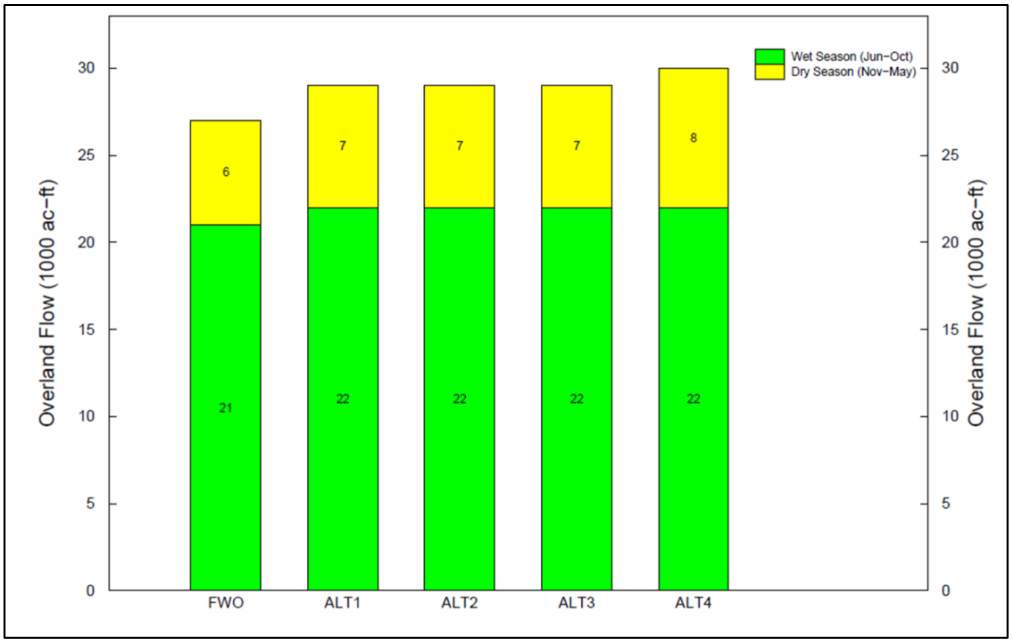


Figure 6-4. **Average annual overland flow across Transect 23A (southward flow in southern ENP; Craighead Basin).**

Salinity Performance Measure

The first of the Florida Bay salinity performance measure results (regime metric) are shown in **Figure 6-5**. This reflects the similarity of an alternative's middle two quartile ("mid-quartile" or "interquartile") salinity values with those of the NSM-based targets. Complete overlap with NSM would yield a value of 1.0 (complete restoration) and no overlap yields a value of 0. Wet season and dry season results are shown. The plots show lift in both seasons for all regions (except the east region during the dry season) for all alternatives compared to FWO. Lift during the wet season is higher than during the dry season for all regions. Generally, for all regions and seasons, the alternatives' sequence of best index scores is: Alt 4>Alt3>Alt1>Alt2. Not shown in this report are the total or absolute index scores, which indicate that conditions in Florida Bay are always better (relatively closer to the NSM target) in the wet season than dry season – dry season conditions are typically very poor.

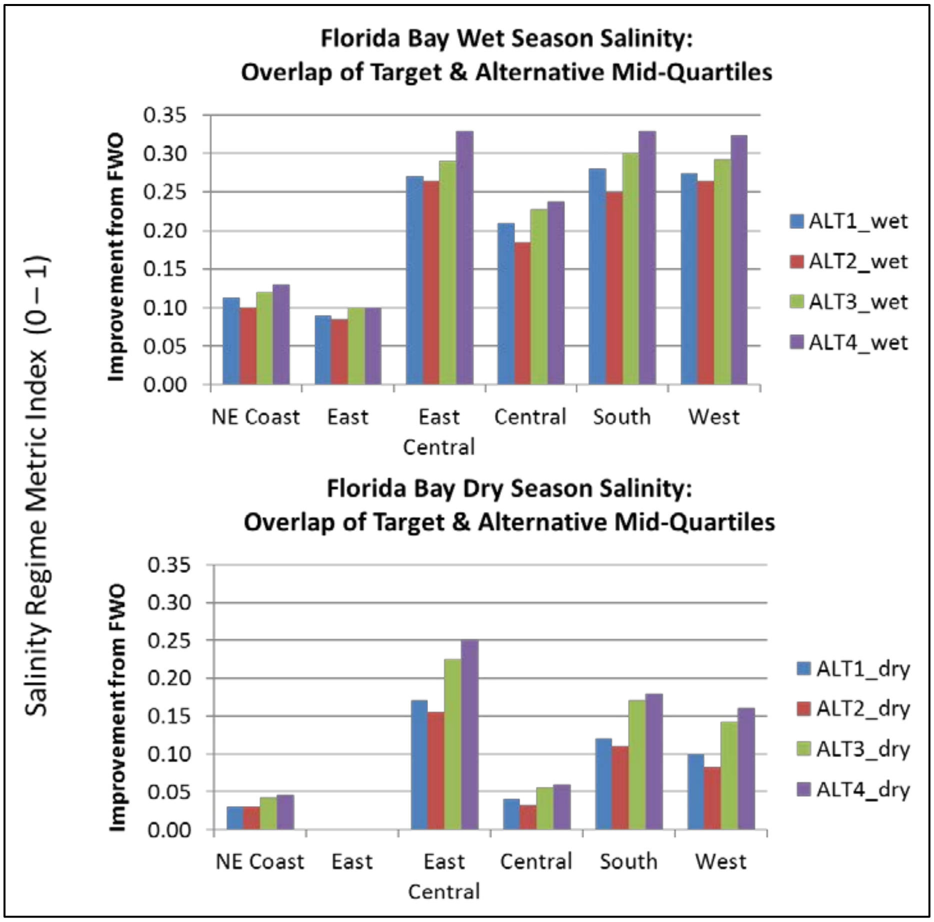


Figure 6-5. **Histogram plot of salinity regime metric comparing CEPP alternatives to FWO (wet season shown in top plot and dry season in bottom plot). Dry season values from alternative in the East zone are zero.**

The high-salinity metric scores for the four alternatives compared to FWO are shown in **Figure 6-6**. This metric indicates the frequency of unnatural and harmful high salinity conditions. It shows a similar lift pattern to that of the regime metric, with generally more lift occurring in the wet season except for the East-central Region. For this metric, the rank of alternatives is Alt4>Alt3>Alt 1and Alt2 for almost all regions and seasons. In several cases, Alt 1 and Alt 2 appear to be equal. Also, the East Region shows no lift in the dry season over FWO, as was the case for the regime metric.

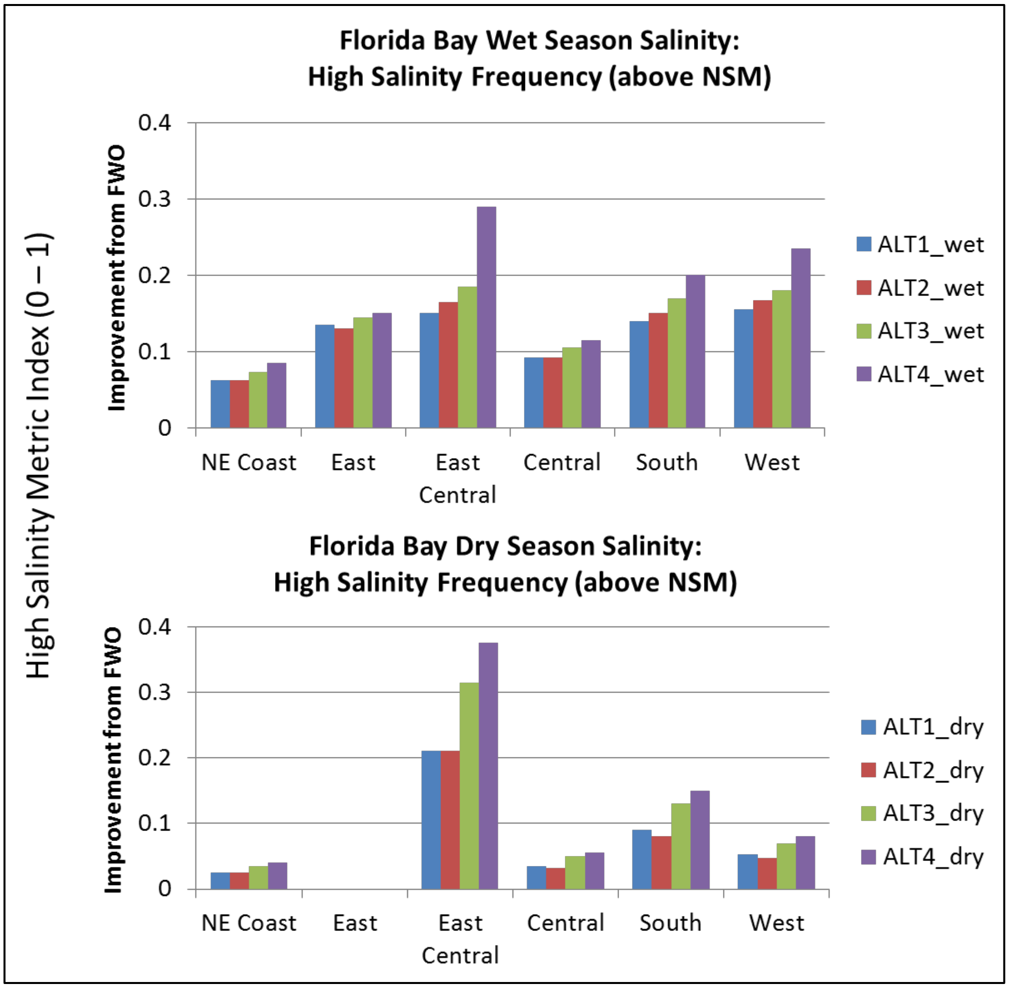


Figure 6-6. Histogram plot of high-salinity metric index comparing CEPP alternatives to FWO (wet season shown in top plot and dry season in bottom plot). Dry season values from alternatives in the East zone are zero.

The third of the three Florida Bay salinity performance measure metrics—the salinity offset—is shown in **Figure 6-7**. This metric is the difference between an alternative's mean salinity and the NSM target's mean salinity. The values are absolute salinity units ("psu" is practical salinity units, which are nearly equivalent to parts per thousand). Lower values mean the alternative is closer to the NSM target. The results show that all four alternatives generally decrease mean salinities about 2 psu closer to the NSM target, except in the East zone, which is more hydrologically isolated from the Everglades than other zones. Decreases in salinity for all zones and both seasons were greatest for alternative 4, with the same overall ranking as for the other two metrics: Alt4>Alt3>Alt1>Alt2. Note that this salinity offset metric was not included in habitat unit calculations of the CEPP Benefits analysis.

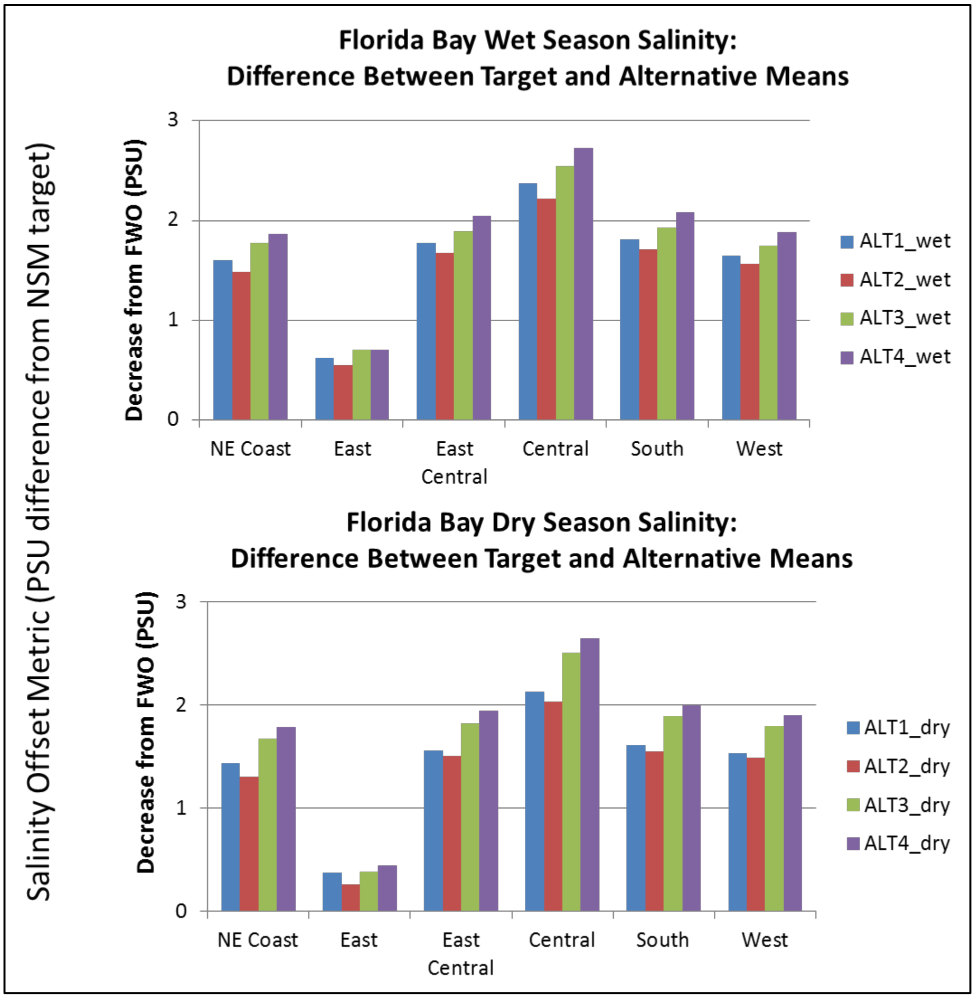


Figure 6-7. Histogram plot of mean offset metric index comparing CEPP alternatives to FWO (wet season shown in top plot and dry season in bottom plot). Each value is a salinity decrease from the FWO, with this increment being closer to the NSM target.

An example of the ribbon plots used to graphically display the regime metric for individual salinity stations is provided in **Figure 6-8**. The plots show the middle two quartiles of all daily data for the model runs period of record (36 years) for all alternatives, FWO and ECB for Terrapin Bay, which is located along the northern edge of the Central Region ("TB" in Fig.1). In FWO and EC there is very little overlap with the target, and when overlap occurs it does so in the wet season. All alternatives show significantly more overlap compared to FWO and ECB, but again it occurs mostly during the wet season. There is minimal overlap during the dry season. The blue lines correspond to the maximum and minimum of alternative 2's 75th percentile values. Alternative 4 had a 3.1 psu lower corresponding maximum and slightly lower minimum. Alternative 3's corresponding values fell in between the alternative 2 and alternative 4 values, and alternative 1 was very similar to alternative 2.

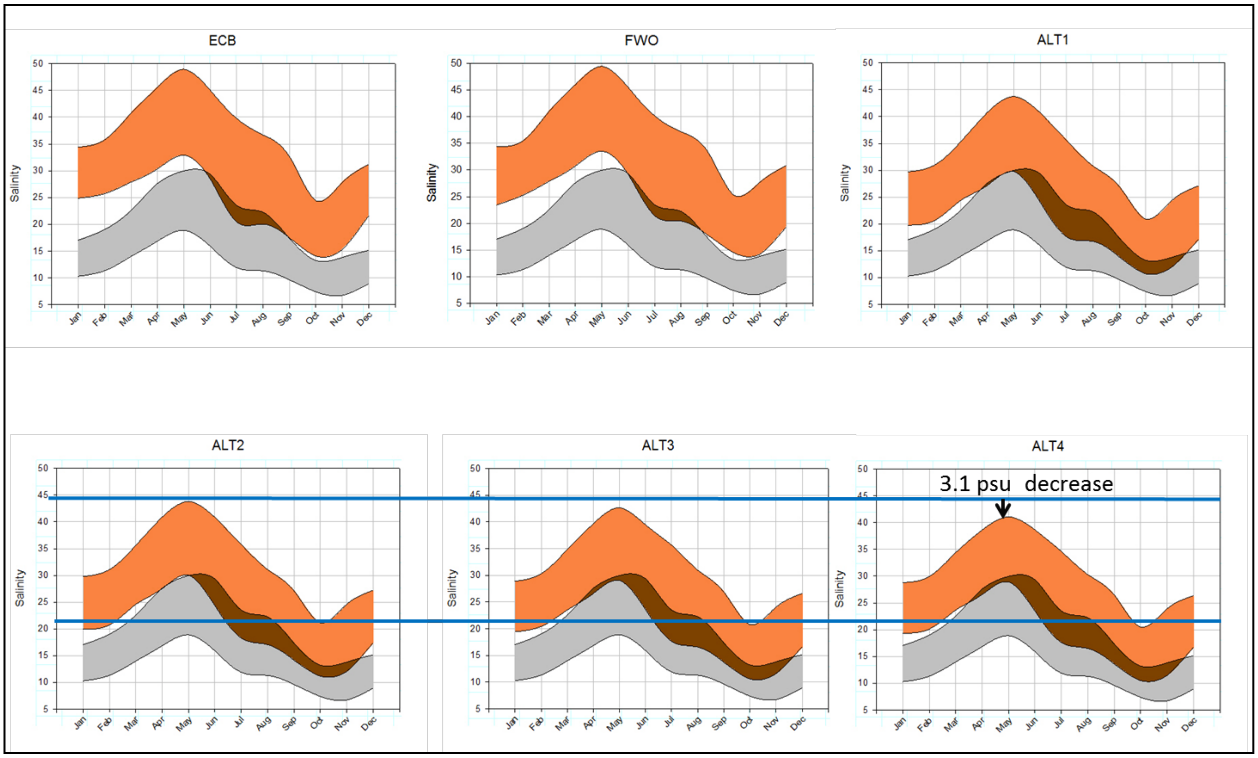


Figure 6-8. **Ribbon plots showing salinity mid-range regime overlap in Terrapin Bay for the four alternatives, FWO and ECB.**

<u>Habitat Suitability Indices and Submerged Aquatic Vegetation (SAV) Simulation Model</u>

Juvenile Crocodiles:
Results from applying the salinity data into the juvenile crocodile HSI is shown in **Figure 6-9**. The plot shows the lift (alternative minus FWO) of an index of juvenile crocodile growth and survival at sites along the northern Florida Bay shoreline for all years of the model runs. Sites in the orange box historically have had the most crocodile nesting. For the four sites with the highest predicted growth and survival, alternative 4 appears to perform better than the other alternatives. However, the difference in performance between alternatives is very subtle. For example, the maximum difference between alternative 4 and alternative 2 occurred in Terrapin Bay and is only about 0.02 units of the 0-1 scale index. Also, determination of any statistical significance between alternatives is not possible. Not surprisingly, the ranking of alternatives follows the salinity performance measure ranking (4>Alt3>Alt1>Alt2) because salinity is the only driver for the HSI, as it is for the other two HSIs reported below. Note that for the three locations that have the lowest crocodile HSI performance, there is almost no difference between alternatives, with alternatives 3 and 4 performing nearly identically.

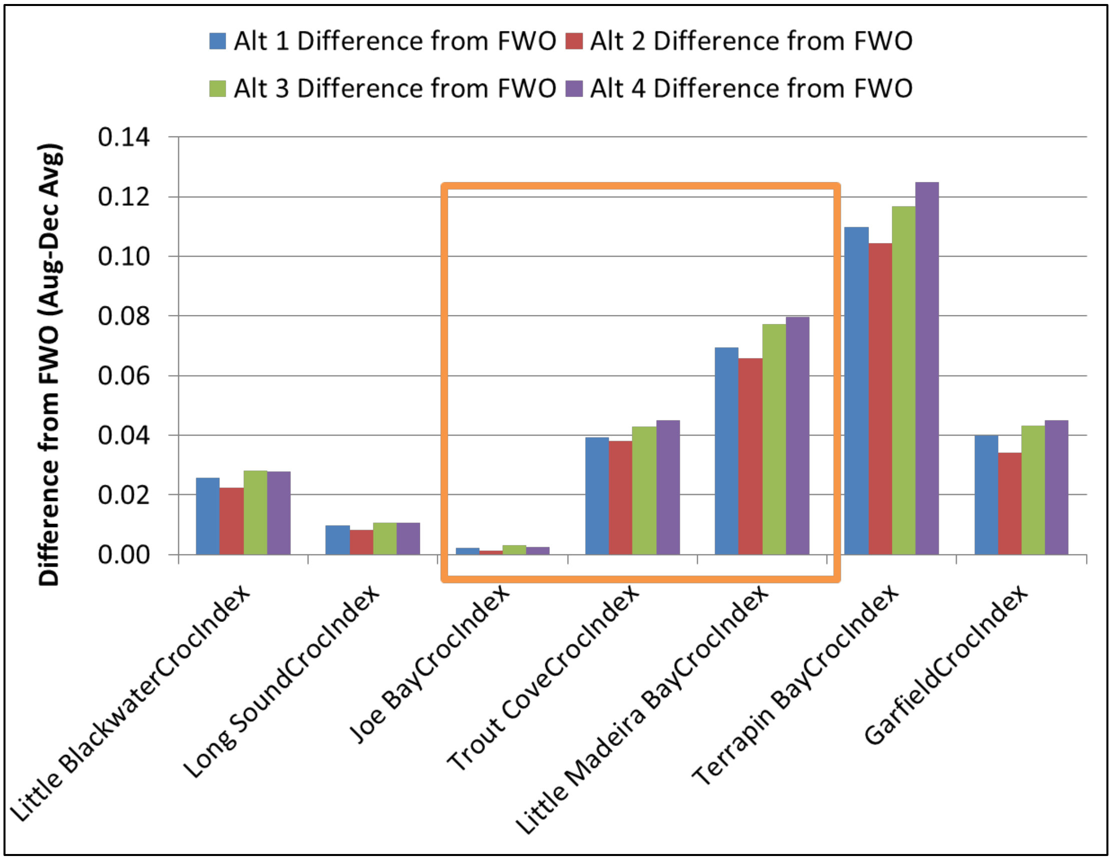


Figure 6-9. **Histogram showing the results of the juvenile crocodile HSI for 7 locations of know crocodile nesting areas. Index values show lift provided by alternatives compared to FWO.**

Results of the juvenile crocodile HSI performance for an extremely dry (1989) year are shown in **Figure 6-10**. For the three highest performing locations (Trout Cove, Little Madiera Bay, and Terrapin Bay), alternative 4 performed noticeably better than the other three alternatives. However, determination of any statistical significance between alternatives is not possible. At sites with very low lift values (<0.02), differences between alternatives was minimal.

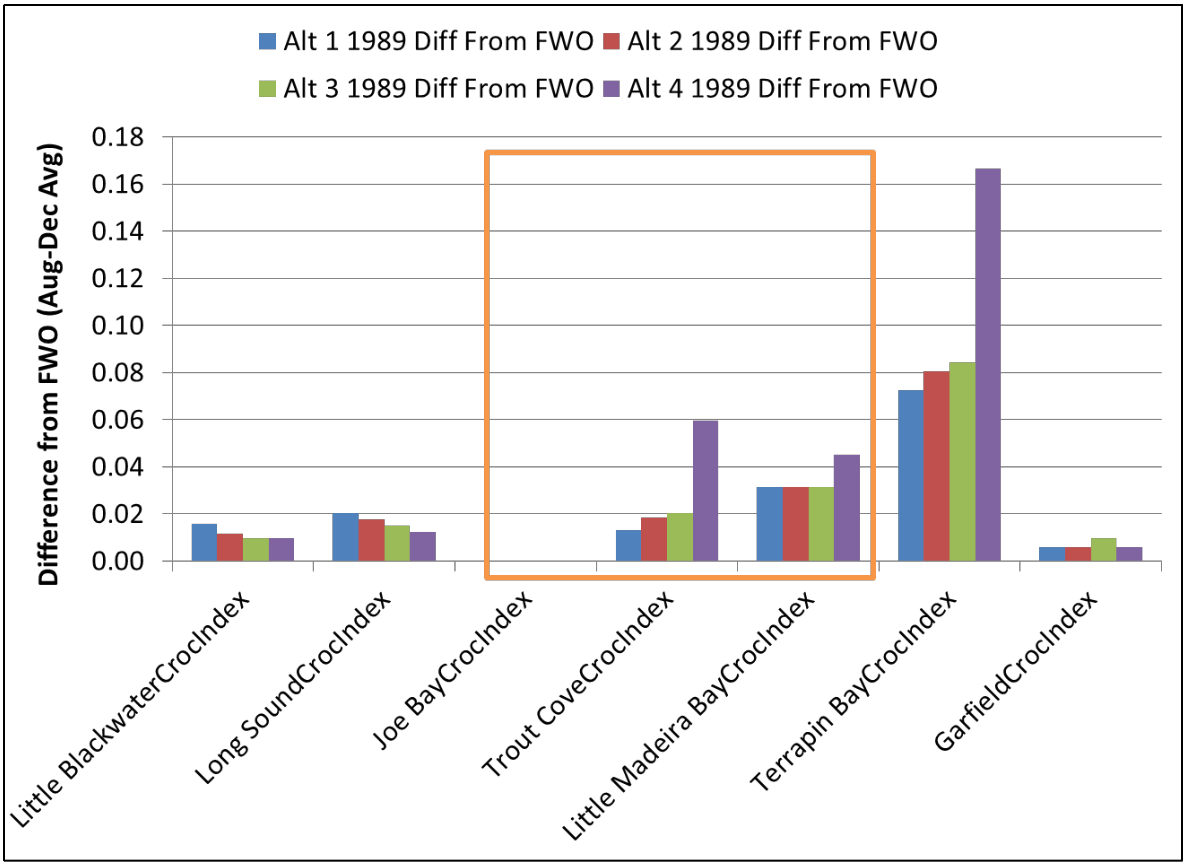


Figure 6-10. **Histogram showing the results of the juvenile crocodile HSI for 7 locations of known crocodile nesting areas during 1989 (very dry year). Index values show lift provided by alternatives compared to FWO.**

Juvenile Spotted Seatrout:
The juvenile spotted seatrout HSI model was run on the monthly average salinities from May through November to coincide with spotted seatrout juvenile recruitment for all CEPP scenarios. The HSI model output from the salinity monitoring stations in Florida Bay was gridded to produce spatial distributions of HSI scores for each month. This allowed for the calculation of area of optimal juvenile spotted seatrout habitat in square kilometers. The mean area of optimal juvenile spotted seatrout for each scenario for the entire period of record is shown in **Figure 6-11**. The error bars reflect the standard error for the data set. The natural system model serves as the target for this analysis. It had the largest mean area of optimal juvenile spotted seatrout habitat at 368 km^2. The future without project was the lowest followed by existing conditions baseline. All four CEPP alternatives showed improvements over FWO and ECB. A Mann-Whitney U-test was applied to conduct pair-wise comparisons among all of the scenarios. All four CEPP alternatives had significantly higher areal extent of optimal habitat for juvenile spotted seatrout (α=0.1) compared to FWO. However, there were no significant differences among any of the alternatives (α=0.1).

To ease in the interpretation of the spotted seatrout data, the percent increase in area of optimal juvenile spotted seatrout relative to the future without project is depicted in **Figure 6-12**. The four CEPP alternatives showed increases from 44% for alternative 1 up to 65% for alternative 4. Alternatives 2 and 3 were in the middle showing 49% and 52% increase, respectively. The juvenile spotted seatrout analysis shows that all four CEPP alternatives showed statistically significant improvement over FWO.

The differences among the alternatives were not statistically significant, but suggest alternative 4 has the highest potential to show the greatest gains for spotted seatrout in Florida Bay.

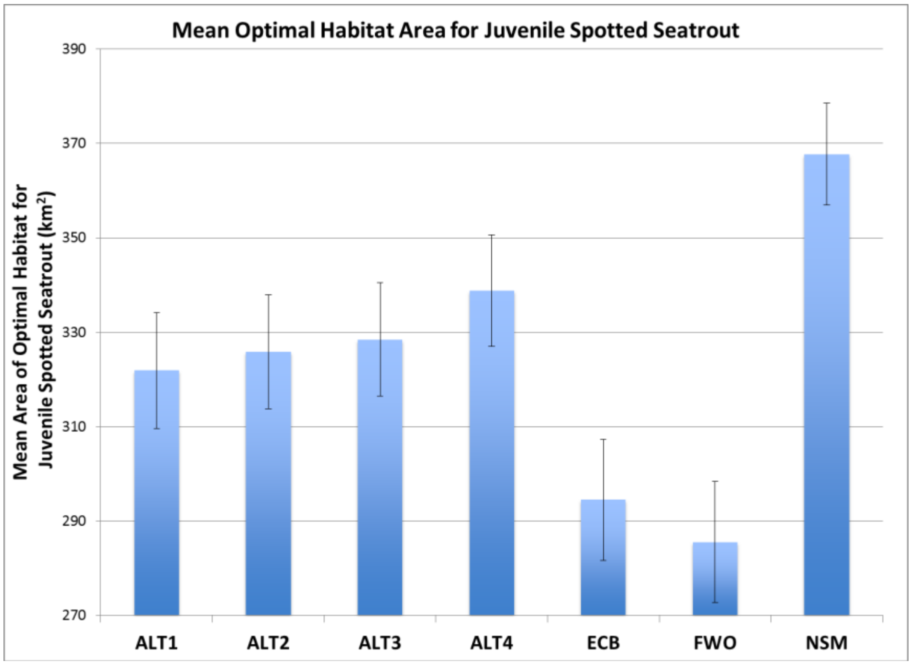


Figure 6-11. **Histogram showing the mean optimal habitat area of the juvenile spotted seatrout HSI for NSM (target), ECB, FWO and the four CEPP alternatives.**

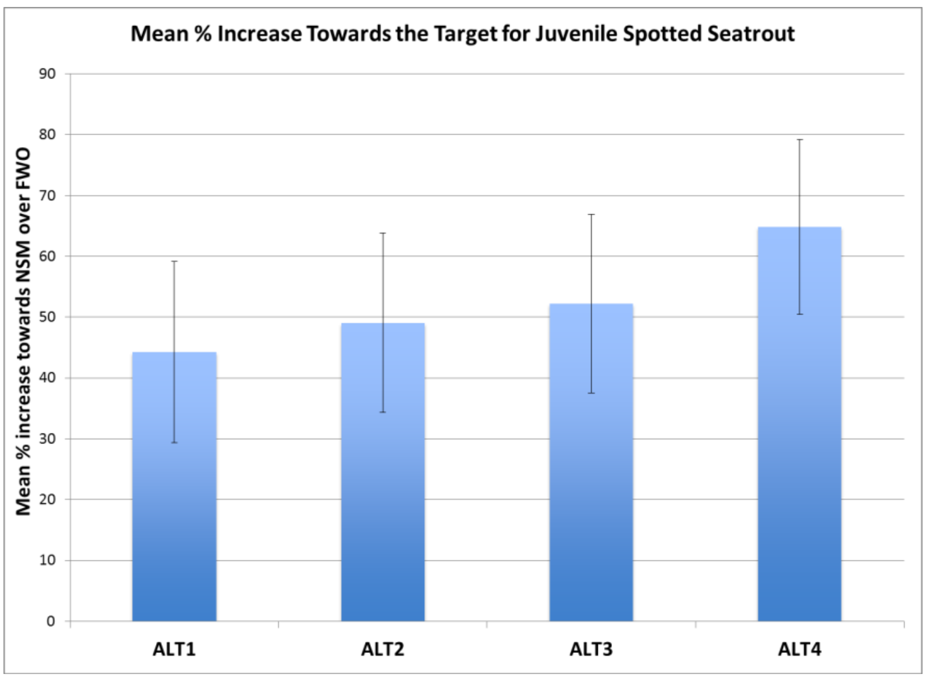


Figure 6-12. **Histogram showing the mean increase towards the target for the juvenile spotted seatrout HSI for the four CEPP alternatives relative to FWO.**

Pink Shrimp:

Results of the 41-year simulations of potential harvests from two representative Florida Bay basins, Whipray Basin in north central Florida Bay and Johnson Key Basin in western Florida Bay, are shown in **Figures 6-13** and 6-**14.** Results show the lift above FWO (as percent of FWO) in potential harvests from each of the four alternatives. The equation for calculating lift as percent of FWO was as follows: 100 x (ALT_x – FWO) / FWO, where ALT_x is simulated potential harvest from a given alternative and FWO is simulated potential harvest from future without salinity conditions. Each alternative provides lift in potential harvest over FWO. The lift in each case is a small percentage of FWO (i.e., 1.05%, at most). In both areas, the lift provided by Alt 4 is greater than that of the other three alternatives. Alternative 1 provides the least lift. Variation across alternatives in most years is less than inter-annual variation.

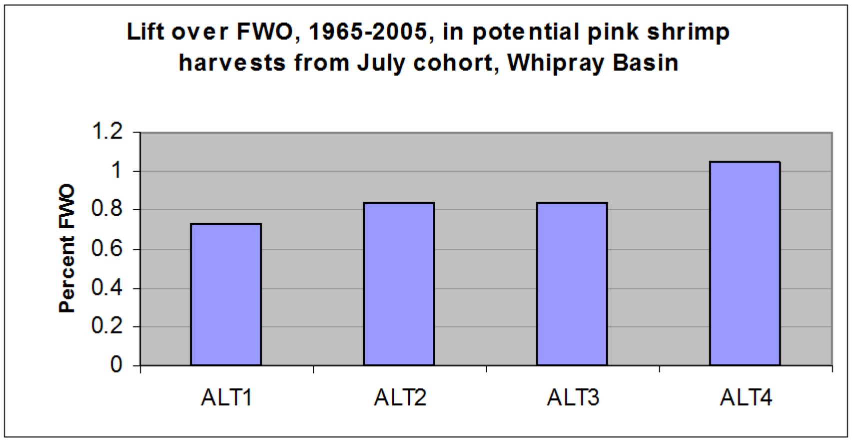


Figure 6-13. Histogram showing the results of the potential pink shrimp harvest in Whipray Basin for the 1965-2005 period of record for model output.

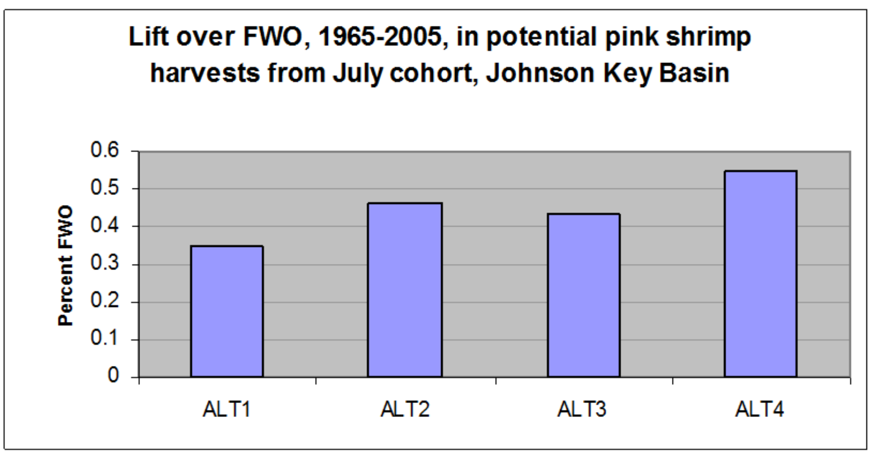


Figure 6-14. Histogram showing the results of the potential pink shrimp harvest in Johnson Key Basin for the 1965-2005 period of record for model output.

Submerged Aquatic Vegetation

The desired outcome of restoration of freshwater flows is a more diverse, mixed SAV community, characterized by enhanced *Ruppia* habitat in the northern sites and mixed *Thalassia-Halodule* in sites farther from freshwater sources. Downstream sites modeled included TR (Little Madeira Bay downstream of Taylor River mouth), WB (Whipray Basin in the central bay) and TC (Trout Cove in the eastern bay). The TC model is not yet fully calibrated and provisional results are provided here for illustration purposes only.

The SEACOM output for TR under NSM hydrology **(Fig. 6-15**) shows a fully diverse mix of SAV species under the wetter conditions resulting from greater freshwater flows from the pre-drainage Everglades relative to the ECB **(Fig. 6-16**). *Thalassia* is more constrained by lower salinities under NSM, while *Halodule* and *Ruppia* thrive. The FWO scenario for Taylor (not shown) reflects little change from the ECB, with no *Ruppia* present and stable *Thalassia* and *Halodule*. CEPP alternatives 3 and 4 produce the most favorable outcomes for restoring Florida Bay SAV at Taylor River (Alt 4 shown in **Fig. 6-17**). Both result in mixed stable communities of three SAV species. Alternatives 1 and 2 both produce similar results, though with less *Ruppia*. NSM conditions for Whipray (not shown) reflect a stable mix of *Thalassia* and *Halodule*, with *Thalassia* dominating and no presence of *Ruppia*. These results are similar to the ECB (**Fig. 6-18**) and FWO scenarios for Whipray, indicating little difference between historic pre-drainage conditions and current conditions at that site, which is distal from freshwater sources in the central bay. All four CEPP alternatives for WB show slight increases in *Halodule*, slightly improving the balance of SAV, with no occurrence of *Ruppia*.

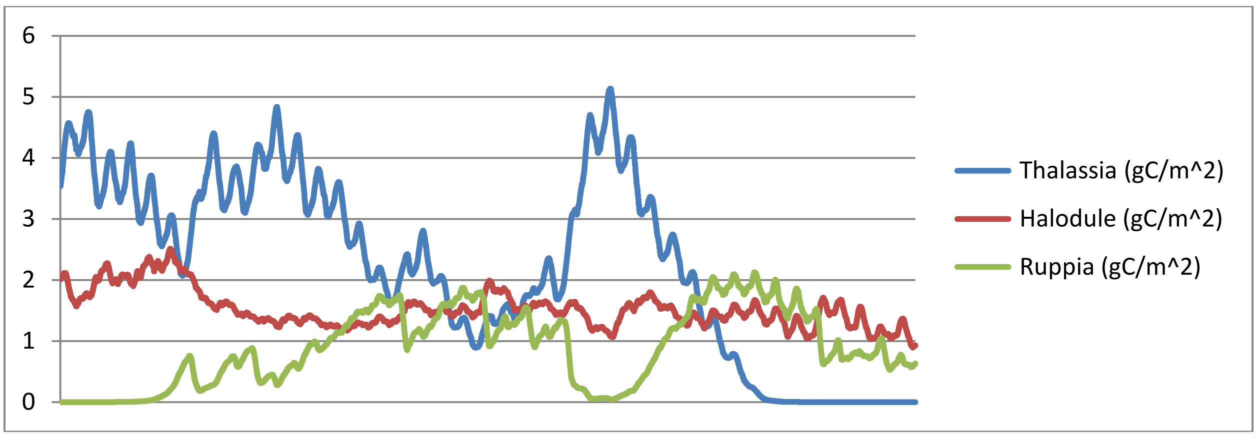


Figure 6-15. Seagrass community at Little Madeira Bay/Taylor River (TR) under NSM hydrology; 40-yr simulation.

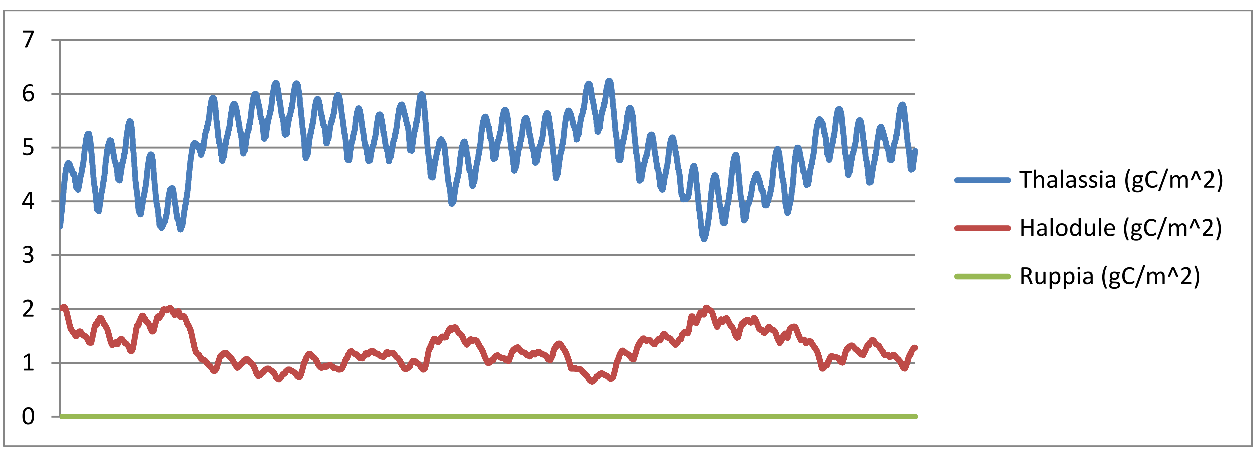


Figure 6-16. Seagrass community at Little Madeira Bay/Taylor River (TR) under ECB hydrology (similar to FWO).

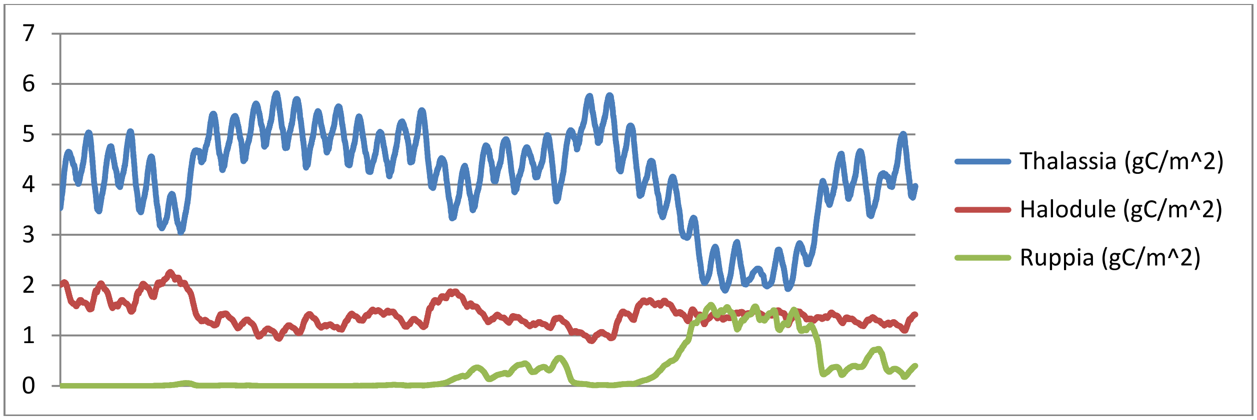


Figure 6-17. **Seagrass community at Little Madeira Bay/Taylor River (TR) under Alt4 hydrology (similar to Alt3).**

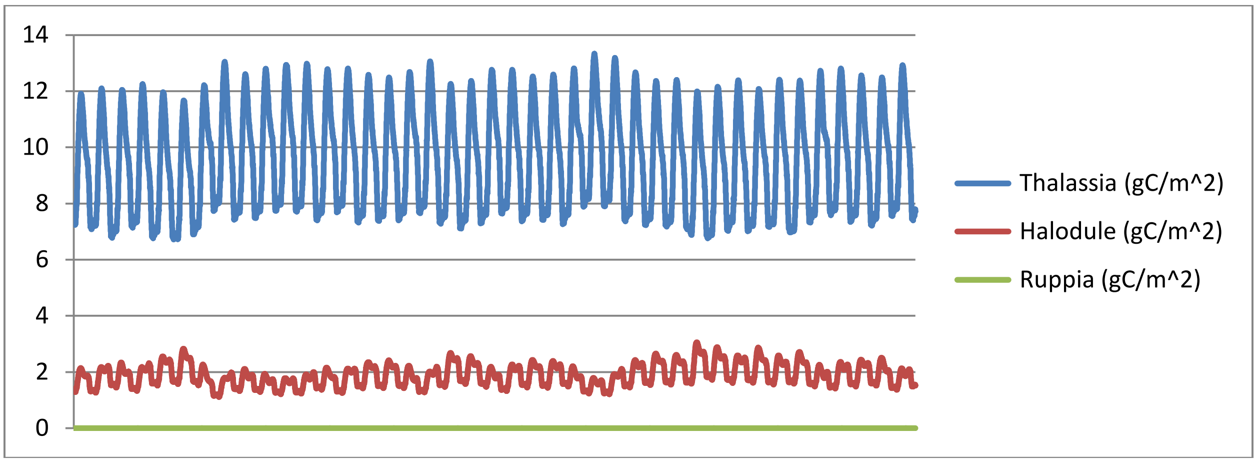


Figure 6-18. Seagrass community at Whipray Basin (WB) under ECB hydrology; 40-yr simulation.

For Trout Cove, downstream of Joe Bay and the C111 Basin, both the ECB (**Fig. 6-19**) and FWO (not shown) runs exhibit a healthy mixed community of *Thalassia-Halodule* with no presence of *Ruppia*. For each of the CEPP alternative runs, the Trout Cove SAV community was greatly improved with a strong presence of the low-salinity *Ruppia* species and a better balance of *Thalassia* and *Halodule*. Alternative 4 (**Fig. 6-20**) produced the best results, followed in order by alternatives 3, 1 and 2. Results for Trout Cove are provisional. SEACOM model results indicate that in areas influenced by Everglades discharge, the SAV community stands to be significantly improved by CEPP, with alternative 4 producing the most favorable results, followed closely by alternative 3.

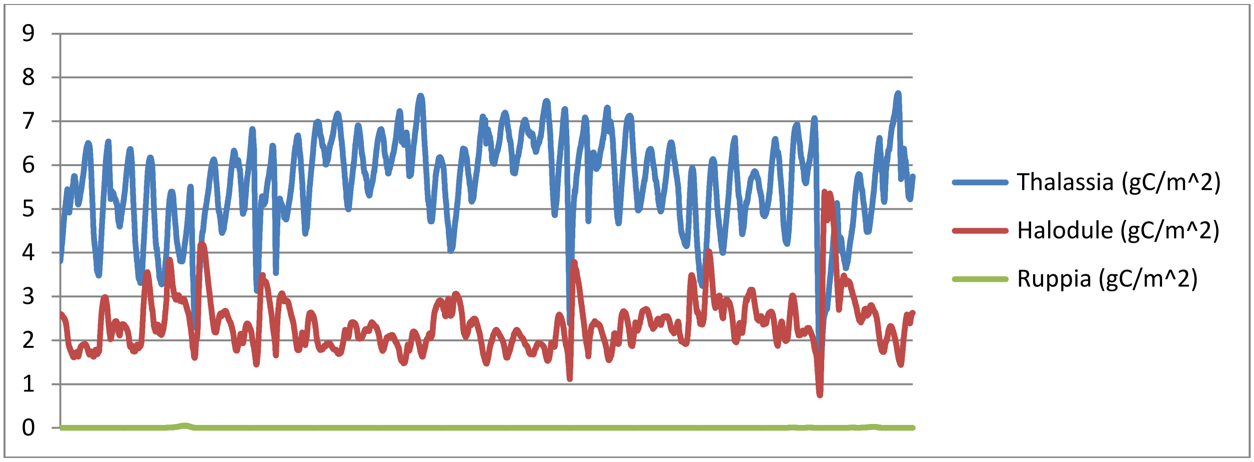


Figure 6-19. Seagrass community at Trout Cove (TC) under ECB hydrology (similar to FWO); 40-yr simulation.

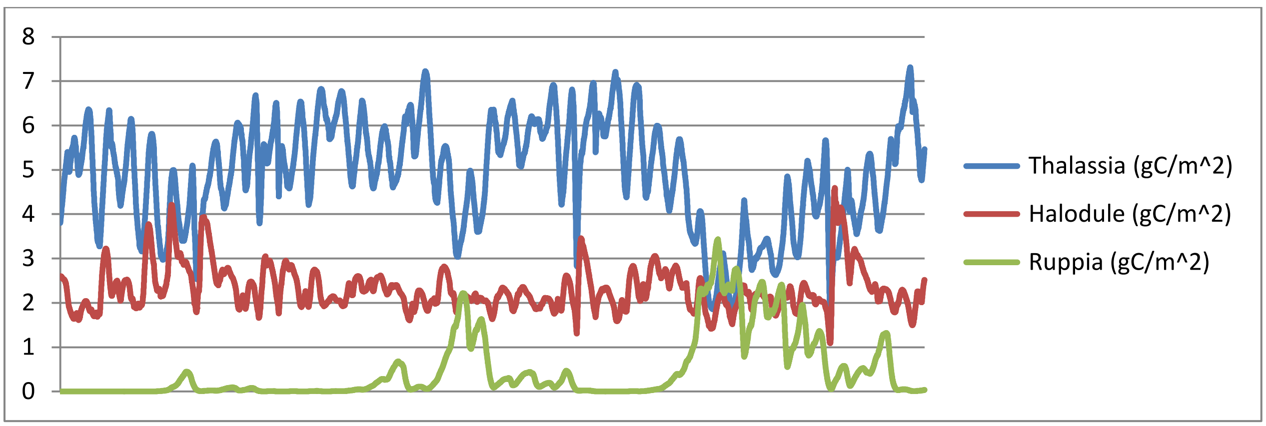


Figure 6-20. Seagrass community at Trout Cove (TC) under Alt 4 hydrology (similar to Alt 3).

Biscayne Bay

Flow at Coastal Structures

Evaluation of the coastal structure flow begins by comparing total flows at all coastal structures for ECB, FWO, and the four CEPP alternatives. Results indicate that flows under FWO and all alternatives are greater than ECB, but not by much. Alternative 2 provides the most additional flows at 7% more than ECB; whereas, alternative 4 provides only 0.3% more water than ECB. Just as importantly, all alternatives except alternative 2, provide less flow to the bay than FWO. Alternative 4 coastal structure flows are 4% less than FWO (about 62 cfs/year), which is the alternative that has the greatest reduction in flows compared to FWO. Alternative 2 provides 3% more flows to the bay compared to FWO.

Table 6-1. **Mean annual flows for all Biscayne Bay coastal structures. Differences between annual means off all alternatives compared to ECB and FWO (expressed in percent).**

Total Flows at Biscayne Bay Coastal Structures	ECB	FWO		Alt1			Alt2			Alt3			Alt4		
	Mean	Mean	% dif ECB mean	Mean	% diff ECB mean	% diff FWO mean	Mean	% dif ECB mean	% diff FWO mean	Mean	% dif ECB mean	% diff FWO mean	Mean	% dif ECB mean	% diff FWO mean
	1234.2	1299.3	+5	1285.4	+4	-1	1333.9	+7	+3	1252.7	+1	-4	1237.1	+0.3	-5
Means are in cubic feet per second.															

The following results break down the Biscayne Bay coastal structure flow by region (North Bay, Central Bay, South Bay, Manatee Bay/Barnes Sound). Results from the flow analyses and salinity performance measure evaluation are presented together for each of the four regions. Flow evaluations are presented as stoplight indicator tables to better illustrate flow conditions relative to FWO. Alternatives are first compared against FWO, then alternatives and FWO are compared against ECB. Because CEPP is to not affect Biscayne Bay in any manner that would worsen it from existing conditions, the comparison of FWO and the alternatives against ECB is necessary to understand the effects of the different model assumptions made in the ECB and future conditions (FWO and alternatives).

North Bay:
The mean annual flow stoplight indicator results for the three coastal structures in the North Bay region are shown in **Table 6-2**. Alternative 2 shows increased flows relative to FWO of up to 4.4% (S-29). Alternative 4 shows a decrease in flows of between 1% and 2% compared to FWO. Alternatives 1 and 3 show no appreciable change in flow relative to FWO.

Table 6-2. **Stoplight table showing flow analysis results for three coastal structures in North Biscayne Bay.**

Structure	Basin	ALT1	ALT2	ALT3	ALT4
S29	C-9	0.00%	4.43%	-0.73%	-2.12%
S28	C-8	-0.21%	1.07%	-0.54%	-0.97%
S27	C-7	0.17%	1.92%	-0.26%	-1.14%
Green=greater than 1% mean increased flows					
White=0% to +- less than 1% mean change					
Yellow=1% to less than 5% mean decrease					

Mean annual flows of each alternative and FWO compared to ECB for the three coastal structures in North Bay are shown in **Table 6-3**, together with the salinity performance measure evaluation results for S-29. Compared to FWO, flows reflect the stoplight table above. Compared to ECB, mean annual flows for all alternatives and FWO are significantly higher at S-29 and slightly higher at S-28. There appears to be little change in flow at S-27. The values for the performance measure are interpreted as the percent of time the daily flows are within the flow target envelope. When compared to FWO, results indicate daily flows fall within the target envelop a slightly higher percentage of time (2% higher for alternatives 1, 3, and 4, and 4% higher for alternative 2).

Table 6-3. Mean annual flows at the three coastal structures in North Bay for all alternatives, FWO and ECB, plus results from the salinity performance measure for S-29 (C-9 canal).

Structure	ECB		FWO			Alt1			Alt2			Alt3			Alt4		
	Mean	% w/in PM	Mean	% ECB mean	% w/in PM	Mean	% ECB mean	% w/in PM	Mean	% ECB mean	% w/in PM	Mean	% ECB mean	% w/in PM	Mean	% ECB mean	% w/in PM
S29	282.8	68	372.3	32	79	372.3	32	81	388.8	38	83	369.6	31	81	364.4	29	81
S28	90.9	-	93.2	3	-	93.0	2	-	94.2	4	-	92.7	2	-	92.3	2	-
S27	115.2	-	114.5	-1	-	114.7	0	-	116.7	1	-	114.2	-1	-	113.2	-2	-

Means are in cubic feet per second.
†PM includes flow from S26+S25B+S25

Central Bay:
The mean annual flow stoplight indicator results for the five coastal structures in the Central Bay region are shown in **Table 6-4**. Alternative 2 again shows increased flows relative to FWO at all structures of up to 4.5% (G-93). Alternative 4 shows a marked decrease in flows at all structures of between 4.5% and 8.9% compared to FWO. Alternatives 1 and 3 show no appreciable change in flow relative to FWO.

Mean annual flows of each alternative and FWO compared to ECB for the five coastal structures in Central Biscayne Bay are shown in **Table 6-5**, together with the salinity performance measure evaluation results for S-26 and S-22. Compared to FWO, mean annual flows reflect the percentage increases or decreases in stoplight table above. Mean annual flows for all alternatives and FWO are lower than ECB at all structures. Compared to ECB, the largest decreases in flow occur under alternative 4 and the least reductions in flow occur under alternative 2. Performance measure results indicate that at the S-26 structure compared to FWO, daily average flows fall within the target envelop 1% of the time more under alternative 1, 1% and 2% of the time less under alternatives 3 and 4, respectfully. There is no change in performance for alternative 2 compared to FWO for the S-26 performance measure. For the S-22 performance measure, alternatives 1 and 2 indicate no change compared to FWO; whereas, alternatives 3 and 4 show a reduction in time within the target envelope of 1%.

Table 6-4. **Stoplight table showing flow analysis results for five coastal structures in Central Biscayne Bay.**

Structure	Basin	ALT1	ALT2	ALT3	ALT4
S26	C-6	-1.98%	17.27 %	-5.50%	-8.93%
S25B	C-4	0.88%	2.64%	-2.64%	-5.27%
S25	C-5	0.00%	1.04%	-4.17%	-6.25%
G93	C-3 West	1.12%	4.49%	-1.87%	-4.49%
S22	C-2	0.88%	3.25%	-2.63%	-5.27%
Green=greater than 1% mean increased flows					
White=0% to +- less than 1% mean change					
Yellow=1% to less than 5% mean decrease					
Red=5% to less than 10% mean decrease					

Table 6-5. **Mean annual flows at the five coastal structures in Central Biscayne Bay for all alternatives, FWO and ECB, plus results from the salinity performance measure for S-26 (C-6 canal) and S-22 (C-2 canal).**

Structure	ECB		FWO			Alt1			Alt2			Alt3			Alt4		
	Mean	% w/in PM	Mean	% ECB mean	% w/in PM	Mean	% ECB mean	% w/in PM	Mean	% ECB mean	% w/in PM	Mean	% ECB mean	% w/in PM	Mean	% ECB mean	% w/in PM
S26†	124.6	35	116.4	-6	32	114.1	-8	33	136.5	10	32	110.0	-12	31	106.0	-15	30
S25B	109.3	-	102.4	-6	-	103.3	-5	-	105.1	-4	-	99.7	-9	-	97.0	-11	-
S25	9.7	-	9.6	-2	-	9.6	-2	-	9.7	-1	-	9.2	-5	-	9.0	-7	-
G93	28.4	-	26.7	-6	-	27.0	-5	-	27.9	-2	-	26.2	-8	-	25.5	-10	-
S22	121.2	12	113.9	-6	12	114.9	-5	12	117.6	-3	12	110.9	-9	11	107.9	-11	11

Means are in cubic feet per second.
†PM includes flow from S26+S25B+S25

South Bay:

The mean annual flow stoplight indicator results for the five coastal structures in the South Bay region are shown in **Table 6-6**. All alternatives show reductions in flow at the S-21, S-21A, and S-20F structures compared to FWO. Alternatives 3 and 4 also show reduction in flows at the S-123 structure compared to FWO, and they show similar overall reductions in flow at the aforementioned structures, which are higher reductions compared to alternatives 1 and 2. Alternatives 1 and 2 appear to show similar overall reductions in flow. Results from S-20G Military Canal) are reported as not valid. The sole function of this canal is to provide stormwater drainage from Homestead Air Reserve Base and is not affected by the overall operation of the South Dade Conveyance System and; therefore, CEPP would have no effect on this canal.

Table 6-6. Stoplight table showing flow analysis results for 5 coastal structures in South Biscayne Bay.

Structure	Basin	ALT1	ALT2	ALT3	ALT4
S123	C-100	0.58%	0.00%	-4.05%	-5.78%
S21	C-1	-4.32%	-1.18%	-15.60%	-16.00%
S21A	C-102	-7.26%	-9.41%	-12.87%	-10.56%
S20G	HARB	*	*	*	*
S20F	C-103	-4.40%	-4.91%	-4.98%	-4.52%
S20	C-107/Model Land	0.00%	0.00%	0.00%	0.00%
Green=greater than 1% mean increased flows					
White=0% to +- less than 1% mean change					
Yellow=1% to less than 5% mean decrease					
Red=5% to less than 10% mean decrease					
Purple= 10% or greater mean decrease					
*Simulation not valid.					

Mean annual flows of each alternative and FWO compared to ECB for the five coastal structures in South Biscayne Bay are shown in **Table 6-7**, together with the salinity performance measure evaluation results for S-123, S-21, S-21A, and S-20F. Compared to FWO, mean annual flows reflect the percentage increases or decreases in stoplight table above. Mean annual flows for all alternatives and FWO are lower than ECB at all structures. Compared to ECB, the largest decreases in flow occur under alternative 4 and the least reductions in flow occur under alternative 2. .Salinity performance measure results indicate that for the S123 coastal structure, there is no change for alternatives 1 and 2 compared to FWO, but alternatives 3 and 4 show slight reduction of 1 and 2 percent, respectively. For the S-21 structure, all alternatives show a reduction in performance compared to FWO ranging from 1 percent reduction under alternative 1 to 8 percent reduction under alternative 3. For the S21A, alternative 1 performs the same as FWO, but the other three alternatives show a reduction in the time flow falls within the target envelope (alternative 2 shows a 3 percent reduction, alternative 3 shows a 5 percent reduction and alternative 4 shows a 4 percent reduction). For the S20F coastal structure, performance measure results indicate all alternatives perform the same as FWO.

Table 6-7. Mean annual flows at the five coastal structures in South Biscayne Bay for all alternatives, FWO and ECB, plus results from the salinity performance measure for S-123 (C-100 canal), S-21 (C-1 canal), S-21A (C-102 canal), and S-20F (C-103 canal).

Structure	ECB		FWO			Alt1			Alt2			Alt3			Alt4		
	Mean	% w/in PM	Mean	% ECB mean	% w/in PM	Mean	% ECB mean	% w/in PM	Mean	% ECB mean	% w/in PM	Mean	% ECB mean	% w/in PM	Mean	% ECB mean	% w/in PM
S123	17.5	22	17.3	-1	22	17.4	-1	22	17.3	-1	22	16.6	-5	21	16.3	-7	20
S21	101.3	67	101.9	1	66	97.5	-4	65	100.7	-1	62	86.0	-15	58	85.6	-15	61
S21A	58.2	46	60.6	4	47	56.2	-3	47	54.9	-5	44	52.8	-9	42	54.2	-7	43
S20G	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
S20F	145.7	43	154.7	6	43	147.9	2	43	147.1	1	43	147.0	1	43	147.7	1	43
S20	6.6	-	6.6	0	-	6.6	0	-	6.6	0	-	6.6	0	-	6.6	0	-
Means are in cubic feet per second. *Simulation not valid.																	

To further investigate flow reductions at coastal structures in South Biscayne Bay, the data were analyzed on a seasonal basis. **Figures 6-21 through 6-24** show histogram plots of the results. At the all but one of the coastal structures on the four major canals in this region, dry season flows always exhibit larger reductions in flow than the wet season compared to ECB. S-20F is the exception and shows an overall increase in flows compared to ECB with most of the increases occurring during the dry season. Also, all alternatives almost always show larger reduction in flow during the dry season compared to FWO than during the wet season.

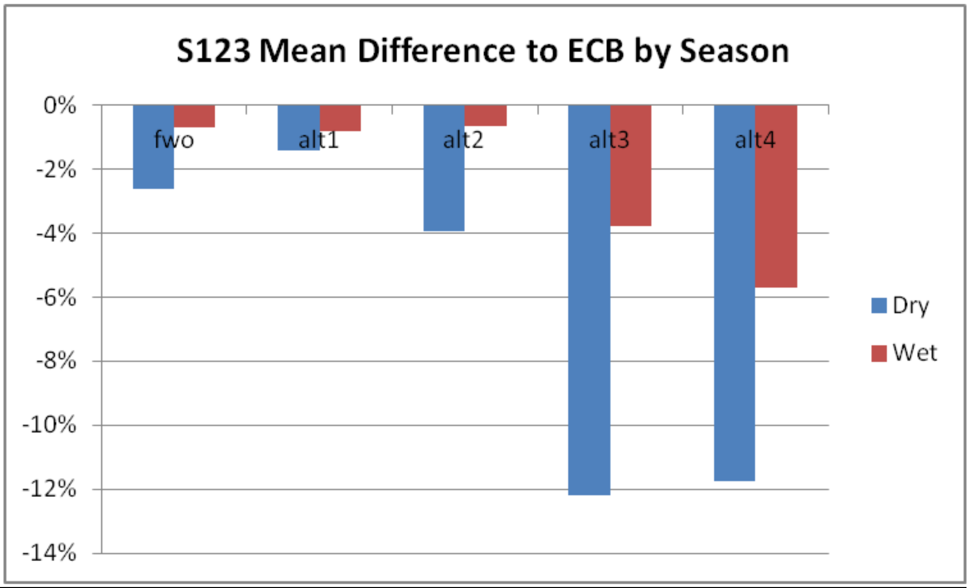


Figure 6-21. **Histogram showing the mean difference (percent) in flow at the S-123 structure (C-100 canal) compared to ECB for FWO and the four CEPP alternatives.**

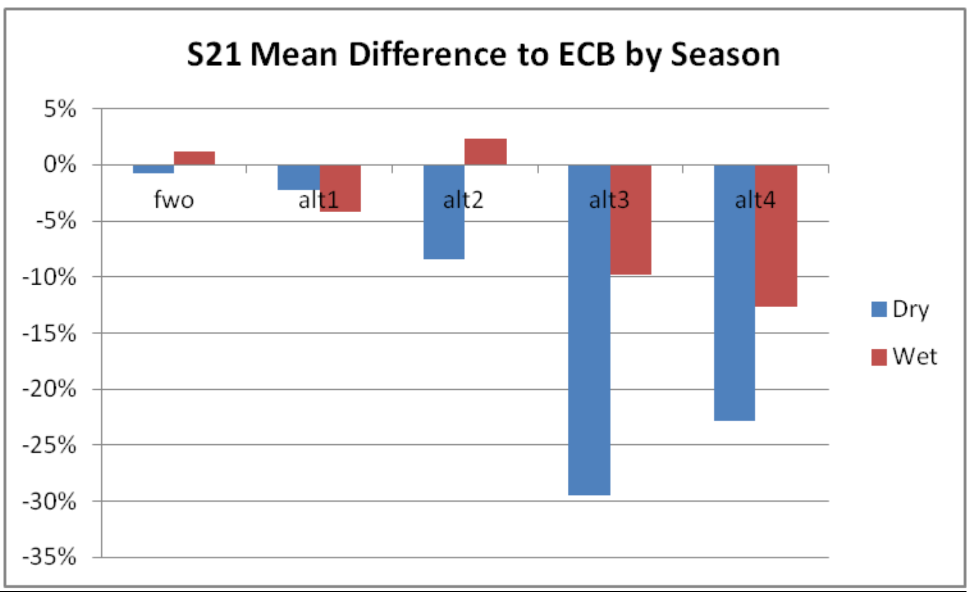


Figure 6-22. **Histogram showing the mean difference (percent) in flow at the S-21 structure (C-1 canal) compared to ECB for FWO and the four CEPP alternatives**

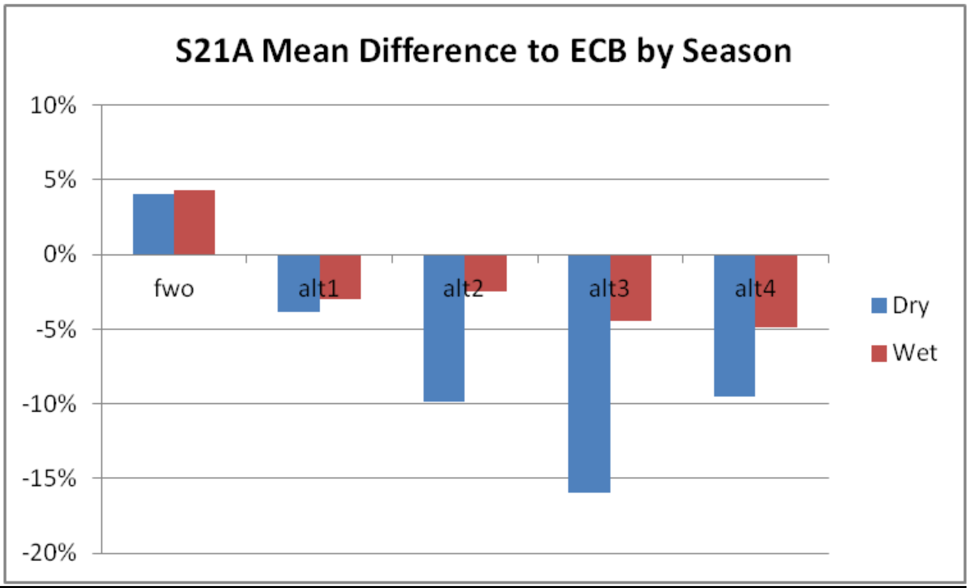


Figure 6-23. Histogram showing the mean difference (percent) in flow at the S-21A structure (C-102 canal) compared to ECB for FWO and the four CEPP alternatives

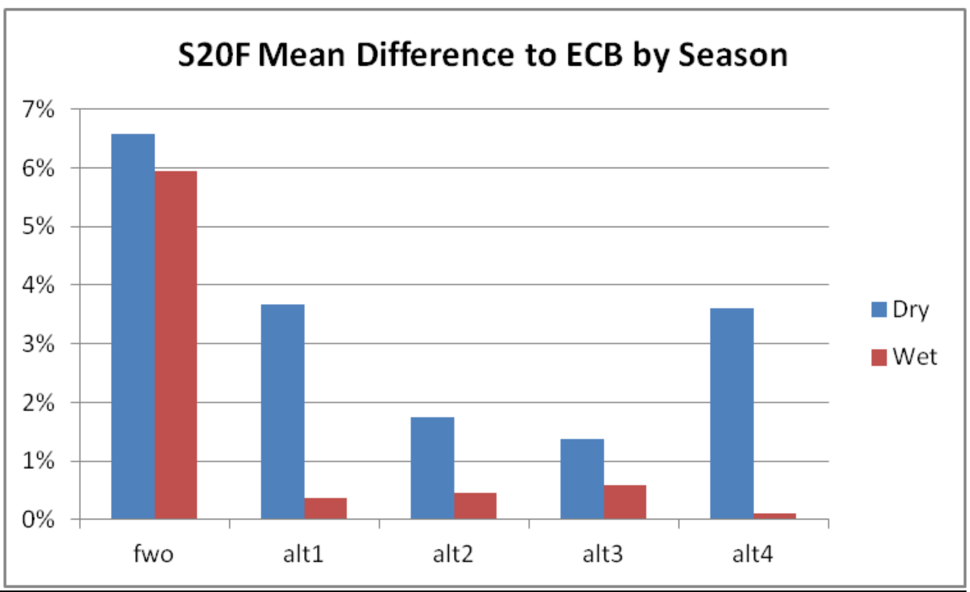


Figure 6-24. Histogram showing the mean difference (percent) in flow at the S-20F structure (C-103 canal) compared to ECB for FWO and the four CEPP alternatives

Manatee Bay/Barnes Sound:
The mean annual flow stoplight indicator results for the two coastal structures providing freshwater flows to Manatee Bay and Barnes Sound are shown in **Table 6-8** on next page. Results show no change in flows at S-20, but significant and similar increases in flow at S-197 for all alternatives compared to FWO. Results from the stoplight analysis for S-197 may be misleading because flows at this structure are relatively small compared to other coastal structures. **Table 6-9** provides the mean annual flows of each alternative and FWO compared to ECB for these two water control structures, together with the salinity performance measure evaluation results for S-197. Flows at S-20 are exactly the same for ECB, FWO, and all alternatives. Note that all alternatives and FWO exhibit significant reductions in flow (from

50-60%) at S-197 compared to ECB. While the desired restoration scenario for Manatee Bay includes the reduction of flows through the S-197 structure, it is important to emphasize that the volume of water lost to the reduction in flows in FWO and the alternatives is not captured by another feature and redistributed to the region. This results in a net loss of freshwater flows to this particular region. Performance measure results indicate extremely poor performance for all scenarios, including ECB. All alternatives and FWO exhibit a decrease in percent time within the target envelop compared to ECB.

Table 6-8. Stoplight table showing flow analysis results for two coastal structures providing flows to Manatee Bay and Barnes Sound.

Structure	Basin	ALT1	ALT2	ALT3	ALT4
S20	C-107/Model Land				
S197	C-111	18.5%	17.4%	21.7%	23.9%
Compared to the base condition (ECB). Green=increased flows and improved PM performance. White=less than 1% mean decrease.					

Table 6-9. **Mean annual flows at the two coastal structures that provide freshwater flows to Manatee Bay and Barnes Sound for all alternatives, FWO and ECB, plus results from the salinity performance measure for S-197 (C-111 Canal).**

Structure	ECB		FWO			Alt1			Alt2			Alt3			Alt4		
	Mean	% w/in PM	Mean	% ECB mean	% w/in PM	Mean	% ECB mean	% w/in PM	Mean	% ECB mean	% w/in PM	Mean	% ECB mean	% w/in PM	Mean	% ECB mean	% w/in PM
S20	6.6	-	6.6	0	-	6.6	0	-	6.6	0	-	6.6	0	-	6.6	0	-
S197	22.8	3.0	9.2	-60	1	10.9	-52	1	10.8	-52	1	11.2	-51	1	11.4	-50	1
Means are in cubic feet per second.																	

Flow at Divide Structures

As noted in Section 6.3 (Evaluation Methods), flows at certain divide structures were also evaluated because of model uncertainty associated with output at the coastal structures. Only flows at the S-338 (C-1 Canal), S-194 (C-102 Canal), and S-196 (C-103 Canal) were included in the analysis to further investigate the apparent severity of flow reductions in the South Bay region. Results show (**Table 6-10** on next page) that all alternatives exhibit reductions in flow compared to ECB. Perhaps more importantly, all alternatives show substantial and alarming reductions in flow compared to FWO. The percent reductions range from 7 to 56%. Percent reductions compared to FWO are generally greatest at the S-196 structure and least at the S-338 structure. Alternatives 3 and 4 appear to have greater flow reductions compared to Alternatives 1 and 2 at S-338; whereas, flow at the other two divide structures are similar for Alternatives 1, 2 and 3. Alternative 4 exhibits less reduction than the other three alternatives at S-194 and S-196.

Table 6-10. Mean annual flows at the three divide structures that feed major canals emptying into South Biscayne Bay for all alternatives, FWO, and ECB. The percent differences form ECB and FWO are also report.

Structure	ECB		FWO			Alt1			Alt2			Alt3			Alt4		
	Mean	% diff FWO mean	Mean	%dif ECB mean		Mean	%dif ECB mean	% diff FWO mean	Mean	%dif ECB mean	% diff FWO mean	Mean	%dif ECB mean	% diff FWO mean	Mean	%dif ECB mean	% diff FWO mean
S338	81.3	3	78.9	-3		70.6	-13	-7	73.4	-10	-7	40.1	-51	-49	45.5	-44	-42
S194	29.0	-19	35.6	23		21.9	-24	-38	21.6	-26	-39	23.3	-20	-35	25.6	-12	-28
S196	12.4	-34	18.9	53		9.1	-27	-52	8.4	-32	-56	8.4	-32	-56	9.9	-21	-48

Means are in cubic feet per second.

Flows at the divide structures were further analyzed for seasonal patterns. **Figures 6-25 through 6-27** show histogram plots of the results. At the S-338, reductions in flow are greatest under alternatives 3 and 4. At the S-338, flow reductions compared to FWO seasonal flow is greater during the dry season than the wet season for all alternatives except alternative 1, which shows the opposite pattern. For the S-194 and S-196 structures, percent reduction in flows compared to FWO are very large for all alternatives. Flow reductions compared to FWO at these two structures show seasonal flows are greater during the wet season than the dry season for all alternatives, and the wet season reductions are remarkably similar between alternatives at these two structures (approximately 60% at S-194 and approximately 70% at S-196. Flow reductions during the dry season at these two structures are least for alternative 4 and greatest for alternatives 2 at S-194 and alternative 3 at S-196.

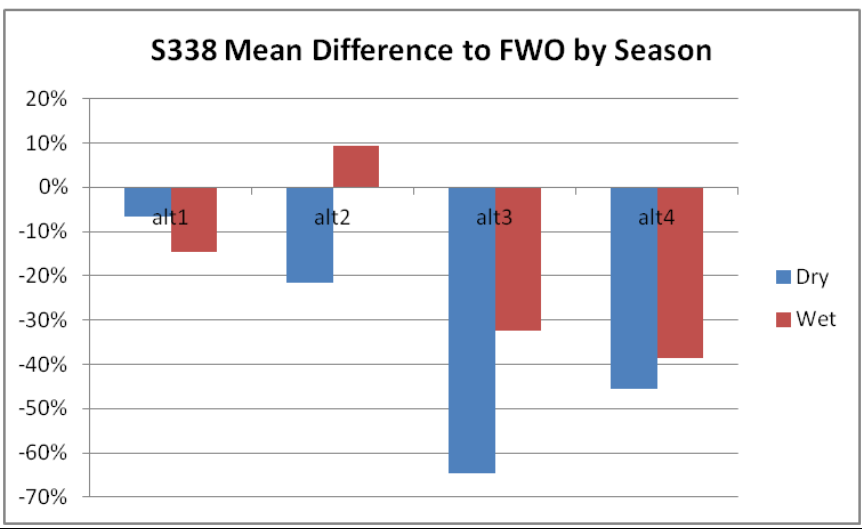


Figure 6-25. Histogram showing the mean difference (percent) in flow by season at the S-338 for all alternatives compared to FWO.

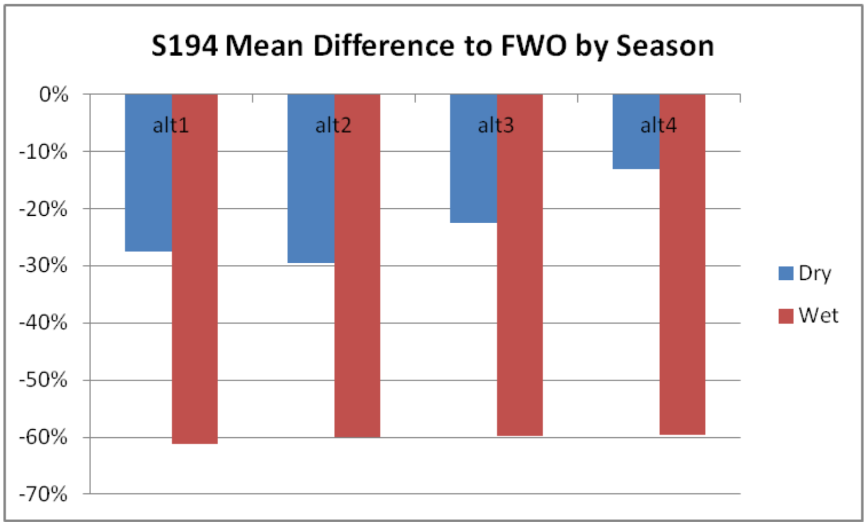


Figure 6-26. Histogram showing the mean difference (percent) in flow by season at the S-194 for all alternatives compared to FWO.

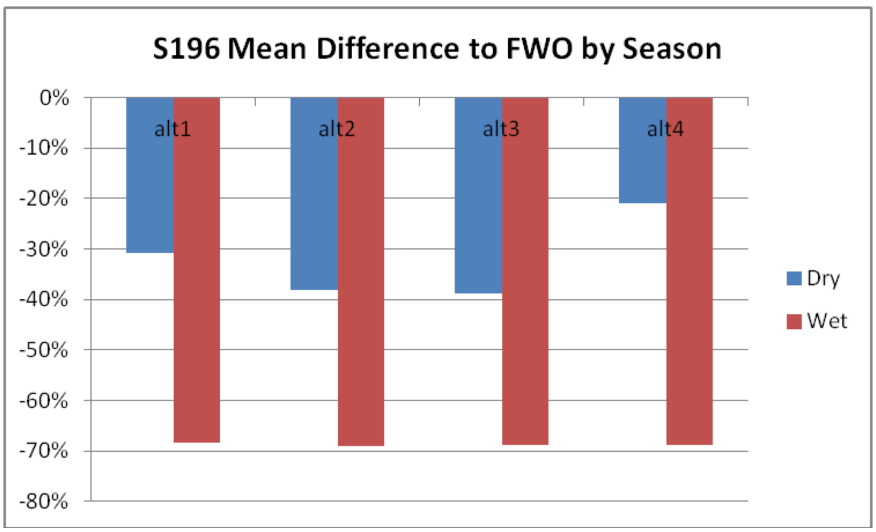


Figure 6-27. Histogram showing the mean difference (percent) in flow by season at the S-196 for all alternatives compared to FWO.

6.5 Summary and Conclusions

Output from the RSM model predicts flow increases in major sloughs providing freshwater to Florida Bay for all CEPP alternatives compared to FWO, with substantial increases predicted for Shark River Slough, These predicted flow increases support the model-predicted salinity improvements in Florida Bay for CEPP alternatives compared to FWO. Flows at Transect 27 in Shark River Slough indicate significant increases (195K to 262K ac-ft/yr) for all alternatives compared to FWO, with alternative 4 providing the largest increase, including a 36% increase over alternative 2. However, flow analyses at Transect 23A in Taylor Slough indicate a slight increase (2-3K acre-feet/year) in flows above FWO for all alternatives, but almost no difference between alternatives.

All CEPP alternatives show an ecologically beneficial decrease in salinity compared to the FWO and ECB in Florida Bay. The Florida Bay salinity performance measure shows lift from all alternatives over FWO, with generally subtle differences between alternatives compared to improvements over FWO or ECB. However, predicted mean salinity for all alternatives is still higher than NSM conditions (about 2 to 9 psu greater than NSM in the dry season across different Florida Bay zones, but about 2 psu closer to NSM than salinity under FWO or ECB). Alternative 4, which yielded more flow through Shark River Slough, improves estuarine salinity conditions compared to the other alternatives The overall ranking of alternatives based on salinity is: alternative 4>alternative 3>alternative 1>alternative 2. Mean bay salinity in alternative 4 is about 0.4 psu less than in alternative 2. There appears to be a greater difference between alternatives when salinity is high. For example, in central Florida Bay, the maximum 75th percentile salinity level at the end of the dry season was 1.7 psu less for alternative 4 compared to alternative 2.

Model-predicted salinity improvements translated to a noticeable lift in juvenile spotted seatrout, pink shrimp, and juvenile crocodile habitat suitability indices and the SAV model results for all CEPP alternatives relative to FWO. However, differences between alternatives are modest and not statistically significant for seatrout, and may not be statistically significant for pink shrimp, crocodiles or SAV. The trend in the HSI data indicate that alternative 4 provides the most lift compared to the other alternatives. The alternative ranking based on the HSIs generally followed the salinity ranking pattern, but not always. In some areas, alternative 1 appears to perform poorer than alternative 2 (e.g., the pink shrimp HSI in Whipray and Johnson Key Basins).

Based on the hydrologic connections between Shark River Slough and the lower southwest coastal areas of Florida (e.g., Whitewater Bay), there is high likelihood that the lower southwest coastal areas would experience significant ecological benefits from any CEPP alternative, perhaps even more benefits than those predicted for Florida Bay. However, benefits to the lower southwest coast could not be quantified to be added to CEPP evaluations due to the lack of salinity and ecological models in that region.

In Biscayne Bay, model results indicate that for total flows at all coastal structures combined all alternatives, except alternative 2, provide less flow to the bay than FWO. Alternative 4 flows are 4% less than FWO (about 62 cfs/year), which is the alternative that has the greatest reduction in flows compared to FWO. Alternative 2 provides 3% more flows to the bay compared to FWO. The evaluation of structure flow by bay region indicates there is generally no change or an increase in flows through the northern Biscayne Bay coastal structures from CEPP alternatives compared to FWO for alternatives 1, 2, and 3. Alternative 4 shows slight decreases in flow compared to FWO at two of the three coastal structures. Modeling exhibits a general reduction in flow at most coastal structures in central and southern Biscayne Bay from CEPP alternatives compared to FWO. Reductions in flows appear to be most extreme at several of the coastal structures in the area of Biscayne National Park and CERP's Biscayne Bay Coastal Wetlands (BBCW) Project. Reductions in flows to the coast may result in increased salinity conditions in Biscayne Bay, negatively impacting the ecological status of Biscayne National Park and other areas of Biscayne Bay. A reduction in flows to the BBCW Project may not allow the project to achieve predicted restoration results as described in the final PIR. In general alternative 4 causes the most reductions in flow and alternative 2 causes the least. Overall ranking of alternatives based on flows and the salinity performance measures at the Biscayne Bay coastal structures is the opposite of that for Florida Bay: alternative 2>alternative 1>alternative 3>alternative 4. Compared to FWO, when reductions in flow are exhibited in the model output they are generally greater during the dry season.

In contrast to the comparison above to FWO flows, the alternatives provide annual average flows to coastal structures equal to or greater than flows provided under ECB. However, this similarity is a result of increased flows to northern Biscayne Bay structures along with decreased flows to central and southern structures. This indicates that Adaptive Management should consider a need to redistribute water in both space and time.

Because the level of model uncertainty of predicted flows at the coastal structures is of concern, the flows at divide structures that provide flows from the Everglades to south Biscayne Bay were included in the evaluation. The three divide structures (S-338, S-194, S-196) that feed freshwater flow from the Everglades to south Biscayne Bay shows substantial reductions in flow for all alternatives compared to FWO (7% to 56% volume reductions compared to FWO). Compared to FWO, reductions at S-338 are generally greater during the dry season; whereas, the opposite seasonal pattern is exhibited for the S-194 and S-196.

The apparent reductions in flows at the divide structures and the central and southern Biscayne Bay coastal structures are of concern because they may negatively impact the ecological status of Biscayne National Park and effectiveness of CERP's BBCW Project, including meeting the BBCW Project's canal discharge targets. Aside from some alternatives providing less flow to the bay compared to FWO in some areas, there is also concern that FWO and CEPP alternatives provide less flow compared to ECB in some areas compared, particularly in central and south Biscayne Bay. Overall, it appears that the alternatives that provide the most water to Everglades National Park provide the least water to Biscayne National Park, and vice versa, may be associated with the level of protection provided by the proposed seepage management features and operational protocols employed. These concerns are to be addressed in the CEPP Savings Clause and Assurances analyses and be incorporated into the CEPP Adaptive Management Plan to be addressed during CEPP's implementation and operation.

6.6 References

Browder, J.A., Z. Zein-Eldin, M.C. Criales, M.B. Robblee, and T.L. Jackson. 2002. Dynamics of pink shrimp recruitment in relation to Florida Bay salinity and temperature. Estuaries 25(6B):1335-1371.

Browder, J. A., V. R. Restrepo, J. Rice, M. B. Robblee, Z. Zein-Eldin. 1999. Environmental influences on potential recruitment of pink shrimp, *Farfantepenaeus duorarum*, from Florida Bay nursery grounds. Estuaries 22(2B):484-499.

Madden, C. J. and A. A. McDonald. 2010. Seagrass Ecosystem Assessment and Community Organization Model (SEACOM), A Seagrass Model for Florida Bay: Examination of Fresh Water Effects on Seagrass Ecological Processes, Community Dynamics and Seagrass Die-off. South Florida Water Management District, West Palm Beach, FL. 120 pp.

Mazzotti, F.J. 1999. The American Crocodile in Florida Bay. Estuaries 22: 552-561.

Mazzotti , F.J. L.A. Brandt, P.E. Moler and M.S. Cherkiss. 2007. American Crocodile (Crocodylus acutus) in Florida: Recommendations for Endangered Species Recovery and Ecosystem Restoration. J. Herp. 41: 121-131.

Moler, P. 1992. American Crocodile population dynamics. Final Report. Study Number: 7532. Bureau of Wildlife Research Florida Game and Fresh Water Fish Commission

$RECOVER_a$. 2012. “Southern Coastal Systems Performance Measure – Salinity in Florida Bay.” The Comprehensive Everlglades Restoration Plan. http://www.evergladesplan.org/pm/recover/recover_docs/perf_measures/062812_rec_pm_scs_salinity_flbay.pdf.

$RECOVER_b$. 2012. “Seatrout Habitat Suitability Index Models.” The Comprehensive Everlglades Restoration Plan. http://www.evergladesplan.org/pm/ssr_2012/hc_scs_fauna_results_2012.aspx.

$RECOVER_c$. 2008. “Southern Estuaries Performance Measure – Salinity”. The Comprehensive Everlglades Restoration Plan. http://www.evergladesplan.org/pm/recover/recover_docs/perf_measures/010709_se_salinity.pdf.